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PERFORATING ABDOMINAL INJURIES

With Special Reference to Reduction in Mortality By the Use of Transfusions and Sulfonamides

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WORLD War II has again focused attention on abdominal injuries. In World War I for the first time abdominal injuries were treated by exploration whenever possible. During this period and the decades following the war a considerable literature arose on the treatment of such wounds. The principles of their operative treatment have not changed materially since they were developed in World War I. The results, even in recent series of cases, are strikingly similar to those published at that time.

In 1916 Wallace reported a study of 1,200 cases of gunshot wounds of the abdomen in the British Expeditionary Force. The mortality of 965 operative cases was 53.9 per cent, which was only a little lower than the total mortality of 60.2 per cent. Lockwood, Kennedy and their associates found a mortality of 51.97 per cent in 356 operative cases reported in 1917. Fraser and Drummond, presenting 313 penetrating wounds of the abdomen at the same time, reported 173 recoveries, a mortality of 55.2 per cent.

A number of excellent articles reporting abdominal injuries in civil life have appeared in the past 20 years. A review of the reported mortalities is interesting in that they are but slightly lower than the statistics for World War I. In 1924 Condict reported a mortality of 45 per cent in 20 abdominal gunshot wounds and a mortality of 28 per cent in 32 stab wounds. Billings and Walkling, reporting 220 penetrating abdominal wounds in 1931, found in operative cases 48.2 per cent mortality in gunshot wounds and 22 per cent mortality in stab wounds. Martin, in 1933, reported a mortality of 46.6 per cent in 180 cases of penetrating abdominal wounds in only 123 of which had there been perforations of viscera. Prey and Foster treated 22 gunshot wounds of the abdomen with a mortality of 68 per cent. A mortality of 21 per cent in 100 stab wounds and 59.3 per cent in 64 gunshot wounds of the abdomen was reported by McGowan in 1935. A year later Oberhelman and Le Count reported on 343 cases of gunshot wounds in the Cook County Hospital with a mortality of 61.4 per cent. Taylor, in 1938, reported a mortality of 59.8 per cent in 87 patients found to have gunshot wounds penetrating the abdominal cavity. Rippy's series of 337 cases of perforating gunshot wounds of the abdomen which had been explored had a mortality of 60.5 per cent. In a

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small series of 35 gunshot wounds and 11 stab wounds Storck was able to report mortalities of 40 per cent and 27.2 per cent, respectively. Recently Hamilton and Duncan have reported an operative mortality of 48.9 per cent in 182 cases of gunshot wounds and 13.8 per cent in 145 abdominal stab wounds. Elkin and Ward, in an excellent report, found a mortality of 46.4 per cent in 181 patients with abdominal rifle or pistol wounds explored on the surgical service of Emory University Hospital. Zinninger briefly mentions 46 penetrating abdominal wounds treated recently at the Cincinnati General Hospital with a mortality of a little less than 11 per cent.

Thus the mortality for gunshot wounds of the abdomen operated on has remained about 50 per cent. This is very similar to the statistics compiled on the battlefields in the last war, although obviously there were many more cases on the battlefield which did not come to operation.

Since the beginning of World War II two interesting papers have appeared. Gordon-Taylor has reported at length on the abdominal injuries occurring at Dunkirk and during the bombing of Britain. He summarized this material by stating that approximately 50 per cent of patients with abdominal injuries, for whom operation is possible, survive. Ogilvie, in a most interesting report on experiences in Africa, reported a mortality of 47.5 per cent in 316 cases of abdominal injury in which a viscus was damaged. In a second series which had not yet been analyzed 247 patients were treated with the astonishing mortality of 34 per cent.

Again and again it has been emphasized that shock and infection are responsible for the great majority of deaths in abdominal injuries (3, 6, 8, 11, 12, 17, 19). In the past 5 years the sulfonamides have come into general use in the treatment of infections, and during this same period the use of blood and blood substitutes in the therapy of shock has received tremendous impetus from the development of blood banks. If these therapeutic measures are of value in the treatment of abdominal injuries their worth should be reflected in the lowered mortality of such injuries during the past 5 years.

Between 1925 and 1943, 146 perforating abdominal wounds were explored by the resident staff of the Johns Hopkins Hospital. Of these patients, 87 were treated between 1925 and 1938 and 59 between 1939 and 1943. Any perforating abdominal wound in which a viscus or a major retroperitoneal structure was injured has been considered as a perforating injury. Penetrating wounds in which the peritoneal cavity was entered but in which no viscus was injured have been excluded. Patients moribund on admission on whom exploration could not be undertaken have also been excluded. Included in the series was 1 patient who died from aspiration of stomach contents during the induction of anesthesia.

The patients in this series were for the most part young, healthy Negro males and females. Stab wounds were commonly inflicted with the so called "switch blade." Gunshot wounds were usually caused by .32 or .38 caliber revolvers. There were a few rifle wounds and but one shotgun wound. Approximately 88 per cent of the patients were operated on within 3 hours of the time of injury.

The operative treatment of abdominal injuries in the Johns Hopkins Hospital did not change materially in the period covered by this series of cases. All the patients were operated upon by the resident staff. Any patient strongly suspected of having a penetrating abdominal injury was subjected to operation, whether objective evidence of an intra-abdominal injury was present or not. The measures for treating shock current at the particular period were employed preoperatively. A systematic exploration of the abdominal cavity was carried out through a rectus incision; the anesthetic agent employed was generally ether. Perforations of hollow viscera were closed whenever possible. Resection of intestine was employed when the extent of the injury precluded simple closure. Injuries to the large bowel were treated in the same way as injuries to the small bowel, and no attempt was made to exteriorize perforations of the colon. Injuries to the liver were packed or were sutured. In 8 instances of injury to the spleen, splenectomy was carried out twice. Injuries to the kidney were treated conservatively. These operative principles are

similar to those so well described in the many contributions to the subject (13, 15, 18, 21).

ANALYSIS OF CASES

The 146 cases of perforating abdominal injuries explored at the Johns Hopkins Hospital between 1925 and 1943 consisted of 91 gunshot wounds and 55 stab wounds. Between 1925 and 1938 there were 87 perforating abdominal injuries, of which 56 were gunshot wounds and 31 stab wounds. Between 1939 and 1943 there were 59 such injuries, 35 of which were gunshot wounds and 24 stab wounds. Table I lists the structures injured in these cases. In many instances several organs were damaged or a single viscus, such as the small intestine, received multiple injuries.

TABLE I.—STRUCTURES INJURED

Small intestine*	52
Large intestine	45
Stomach	44
Liver	39
Mesentery	17
Spleen (2 splenectomies)	8
Kidney (1 nephrectomy)	4
Great vessels	4
Biliary tract	3
Duodenum	3
Pancreas	1
Bladder	1

*11 resections of small intestine with 3 deaths.

Among the 87 cases explored from 1925 to 1938 there were 27 deaths, a mortality of 31 per cent. The mortality in the 31 stab wounds was 25.8 per cent and in the 56 gunshot wounds, 33.9 per cent. Between 1939 and 1943 there were 6 deaths in 59 cases, a mortality of 10.1 per cent. The mortality in the 24 stab wounds was 4.2 per cent: that in the 35 gunshot wounds was 14.3 per cent. The mortality for the total 146 cases was 22.6 per cent.

TABLE II.—MORTALITIES

	1925–38		1939–43	
	Per cent	Cases	Per cent	Cases
Stab wounds	25.8	31	4.2	24
Gunshot wounds	33.9	56	14.3	35
Total	31	87	10.1	59

Analysis of the causes of death in the first group of cases showed 11 deaths due to shock, 4 deaths due to peritonitis, and 5 due chiefly to pneumonia. Two patients died with an infection not accurately located. In 2 instances ileus was the chief cause of death. In 1 patient a gastric fistula and subdiaphragmatic abscess contributed to death. Another died during induction of anesthesia from aspiration of stomach contents. A single patient died from postoperative gastric hemorrhage. Thus in 11 cases death was due primarily to shock and in 11 cases to infection.

In contrast to this, of the 6 deaths occurring between 1939 and 1943, 5 were due to shock and one was probably due to complications arising from a paraplegia. None of the deaths could be attributed to infection alone.

Prior to 1939, 8 transfusions were administered at operation, one of which was an autotransfusion. In the past 5 years 30 patients have received transfusions of blood or plasma, or both, before operation or at operation. The number of postoperative transfusions increased similarly. One patient who succumbed from shock due to uncontrollable bleeding from pelvic vessels received more than 7000 cubic centimeters of citrated blood. Another patient who survived received 3000 cubic centimeters of blood and 500 cubic centimeters of plasma at operation with a transfusion immediately after operation. At the present time a patient arriving in the accident room in a state of shock is immediately given plasma and is matched for transfusion. Unless it is felt that there is continued active intra-abdominal bleeding, transfusions are given rapidly until the patient recovers from shock. If the patient does not respond to multiple transfusions and it is felt that there is active intra-abdominal bleeding, exploration is carried out after a continuous transfusion is started.

In the past 5 years the use of sulfonamides has become an almost routine treatment of patients with perforating abdominal injuries. During this period 46 patients received a sulfonamide in some form. The drug employed and the mode of administration have varied as advances in the use of sulfonamides have been made and new drugs have been added. It is not possible in this small series of cases to compare the efficacy of different methods of sulfonamide administration. At present 10 grams of sterile sulfanilamide usually is placed

in the abdominal cavity and wound of exploration. Sulfadiazine or sulfamerazine is administered after operation by mouth or parenterally.

The number of postoperative complications in the patients who recovered was not materially different in the two groups of cases (Table III); their severity, however, was decreased. There were relatively the same number of wound infections and instances of pneumonia in each group of cases.

TABLE III.—POSTOPERATIVE COMPLICATIONS IN PATIENTS WHO RECOVERED

	1935–38	1939–43
Wound infection	20	15
Pneumonia	8	7
Pneumonia and lung abscess	1	
Pleural effusion	1	
Empyema	3	1
Hemopneumothorax	3	6
Obstruction (immediate or later)	7	4
Wound dehiscence*	1	2
Fecal fistula	4	1
Subphrenic abscess	1	1
Peritonitis		1
Liver abscess	1	
Gas gangrene		2
Arteriovenous fistula of liver		1
Thrombophlebitis		1
Ileus		1
Penile urinary fistula and bladder stones		1
Delirium tremens		1
Head injury and postoperative psychosis	1	

*In several infected wounds there was at least partial wound dehiscence.

OBSERVATIONS FROM STUDY

This group of 146 perforating abdominal wounds represents a relatively uniform series of cases. The injuries were inflicted for the most part on young, healthy patients who were subjected to operation within 3 hours of the time of injury. The operative technique in the hands of the resident staff remained essentially unchanged. The striking reduction in mortality in the years 1939 to 1943 from a previous mortality of 31 per cent to 10.1 per cent certainly can be attributed chiefly to the use of transfusions and sulfonamides. Improvements in anesthesia and the use of constant gastric suction or the Miller-Abbott tube must be considered in this reduction in mortality, but they would seem to have had only a small share in the reduction in mortality. Between 1925 and 1938 ileus was the chief cause of death in 2 instances and certainly contributed to other deaths; aspiration of stomach contents during induction of anesthesia also caused 1 death. No deaths between 1939 and 1943 could be attributed either to ileus or to anesthesia.

The relative value of transfusions and sulfonamides in these cases is difficult to estimate. It is probable that the use of blood and blood substitutes has had a greater influence in the reduction in mortality than the use of sulfonamides, despite the fact that most of the deaths in recent years have been due to shock rather than to infection. It has been noted that patients in shock are more susceptible to infection (3, 8). The improved postoperative condition of patients in the past 5 years with the use of transfusions must have played a large part in their resistance to infection. Loria (9), however, has recently emphasized the value of sulfonamides for such patients.

In the perforating abdominal injuries operated on in the past 5 years death has been due largely to hemorrhage which could not be controlled at operation or to injury so severe that massive transfusions had little effect on the patient's state of shock.

The results reviewed here, of patients treated individually with all the resources of a large hospital, represent a goal unattainable by the military surgeon. The relative simplicity of the wounds, early operation, and concentrated care before and after operation make the mortality figures presented here far lower than those which could ever be obtained on the battlefield. However, this small group of cases does show clearly that the use of transfusions and sulfonamides can effectively reduce the mortality of perforating abdominal wounds.

SUMMARY

1. A total of 146 cases of perforating abdominal injuries were explored at the Johns Hopkins Hospital by the resident staff between 1925 and 1943, with a mortality of 22.6 per cent.

2. In the period 1925 to 1938 the mortality was 31 per cent in 87 cases. This was reduced between 1939 and 1943 to 10.1 per cent in 59 cases.

3. The striking reduction in mortality is due to the frequent use of transfusions and the customary practice of administering sulfonamides.

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THE LATE CONDITION OF NERVE HOMOGRAFTS IN MAN

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OF all the problems connected with the surgical repair of nerve injuries none is more pressing than that presented by the large gap in a main nerve trunk.

Where end-to-end suture is impossible the only rational alternative is some form of nerve graft[1]; but, if this is agreed, there is still uncertainty as to the types of graft which can be employed with some prospect of success. Enough experimental and clinical evidence has accumulated to show that autografts of small caliber are far superior to all others. (Sanders, 1942; Seddon, Young, and Holmes, 1942; unpublished results of one of us—H. J. S.—in 16 cases operated on between 1940 and 1943). Indeed, in rabbits, functional recovery after autografting of the lateral popliteal nerve is as good as that seen after section and immediate suture (Gutmann and Sanders, 1942). Yet even if improvements in technique lead to the establishment of autografting as a valuable operation, the proportion of large gaps that can be dealt with by this means must always be small. In many cases the extent of the lesion and the diameter of the damaged nerve are such that the patient cannot himself provide the material required to fill the gap. In a patient who has suffered amputation of a limb as well as an extensive nerve lesion it may be possible to remove a nerve from the stump and to use it as a graft; or, if there are lesions of great longitudinal extent in two nerve trunks, a segment of the less important nerve may be used to bridge the gap in the other (Seddon; unpublished work). But cases of this kind are exceptional, and usually autografting can be carried out only if a length of cutaneous nerve sufficient to allow the construction of a bridge across the gap can be taken without great inconvenience to the patient.

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[1]Sanders (1942) has reviewed this subject so thoroughly that a résumé of the literature is unnecessary here.

This leads to consideration of the alternatives; homografts and heterografts, either of which may be used fresh, after storage, or preserved by fixation. In spite of all claims to the contrary, the only material which on critical examination gives any prospect of success is the homograft either fresh or stored (Sanders, 1942; Gutmann and Sanders, 1942). There is no longer any doubt that, in a variety of animals, homografts may provide a bridge for regeneration of a number of fibers sufficient to give not merely measurable but useful functional recovery. Nevertheless there are discouraging reports of partial necrosis in some experiments (Merzbacher, 1905; Ingebrigsten, 1915; Eden, 1919), and Sanders and Young (1942) noted a cellular infiltration around and within their homografts, which must indicate that the graft causes a persistent reaction on the part of the host tissue. When stored homografts are used the state of affairs may be even more unsatisfactory. In one of Eden's experiments, where a 5 centimeter gap in the sciatic nerve of a dog had been bridged by a homograft stored for 3 days in physiological saline solution, it was found that after 110 days the graft had been largely replaced by fibrous tissue, only a few patches of degenerate nerve tissue remaining: regenerating axons from the proximal stump of the host nerve had succeeded in penetrating only a very short distance into the graft.

The results of homografting in man are most discouraging. Although Sanders' review suggests that there were 8 successes in 42 cases reported by 8 authors, careful scrutiny of the data fails to reveal any convincing evidence of recovery except in 3 of Duel's (1934) 6 cases of facial nerve homografting. In these the transplanted nerve was, of course, much smaller than in the average transplantation for a nerve injury in a limb, and the gap to be bridged was quite short. (The case reports examined were those of Albert, 1878; Ward, 1890; Robson, 1896; Sherren, 1906; Bethe, 1916; von Enderlen and Lobenhoffer, 1917;

Foerster, 1917; Spitzy, 1917; Dujarier and François, 1918; Eden, 1919; Delagenière, 1924; and Duel, 1934.)

It is curious to find that in spite of these dismal experiences no one except Eden thought it worth while to remove an unsuccessful homograft for histological examination. In 1 case a fresh homograft was removed and examined 9 months after implantation. At first sight the graft appeared to be in the very early stages of Wallerian degeneration, the axons being somewhat fragmented, and the myelin still present as globules. But there were no Schwann cells, although the thick connective tissue strands between the tubes were full of nuclei. (These findings were confirmed by Spielmeyer who examined the same material independently.) In a second case a segment of nerve from an amputated limb was transplanted to a position in the subcutaneous tissue of another patient. The "graft" was removed after 38 days, and similar changes were found. Eden concluded that the nervous elements in a homograft undergo a slow necrosis and are gradually replaced by connective tissue, some of it arising from the graft itself, the rest by proliferation of fibroblasts of the host tissues. Whether this is the invariable fate of homografts in man has yet to be proved, and it is on these grounds that our cases are reported.

Storage of grafts is obviously technically desirable, and grafts have been left for varying periods at temperatures ranging from 0 to 37 degrees C in normal saline or Ringer's solution (Tello, 1914; Ingebrigsten, 1915; Eden, 1919; Sanders and Young, 1942), in vaseline or petrolatum (Dujarier and François, 1918; Huber, 1920), or dehydrated and frozen (Weiss and Taylor, 1943). Since Gutmann and Sanders (1942) found that the cellular reaction was less and the functional result slightly better after the use of homografts stored in Ringer's solution in the refrigerator than after the employment of fresh homografts, it was decided that this method of storage would be employed should the occasion arise.

MATERIAL

Four cases were treated by homografting; in 2 fresh homografts were used and in 2 stored grafts. In 3 cases the grafts were removed later, when it was evident that no recovery was to be expected. The patients were dealt with at the Oxford Nerve Injuries Centre (Wingfield-Morris Hospital) and the operations were performed by the late W. B. Highet, R. B. Zachary, and H. J. Seddon. The suture materials used were: Case 1, human hair; Cases 2 and 3, fine silk; and Case 4, stainless steel wire. The final operations (excision of graft) were performed with a view to determining the prospects of recovery before proceeding to the reconstructive operations required for the treatment of permanent paralysis. It is hardly necessary to describe the reconstructive operations that were carried out.

The early histories of Cases 1 and 2 have already been described in detail as part of a series of traction injuries of the lateral popliteal nerve (Highet and Holmes, 1943).

The purpose of this paper is to describe the late condition of the homograft in the 3 cases in which re-exploration was performed.

HISTOLOGICAL TECHNIQUES

The techniques employed were directed toward demonstrating myelinated and non-myelinated nerve fibers, using a modified Weigert and a silver-on-the-slide method, respectively; in addition the usual routine stains were employed. All the material was examined in paraffin sections: it may be useful to other investigators of similar human homografts to note that these grafts were so densely collagenized as to have much the consistency of tendon; hence simple paraffin embedding should for choice be avoided and replaced by methods designed for the treatment of particularly hard tissues.

CASE REPORTS

CASE 1 (B. 20). A soldier, born 1918. December 1, 1940, he fell down a flight of steps and suffered an adduction injury of the right knee, with avulsion of the head of the fibula and a severe traction lesion of the lateral popliteal nerve. On June 3, 1941 he was admitted to the Wingfield-Morris Hospital, at which time he had complete lateral popliteal paralysis. On June 18, 1941, the damaged segment of nerve, 11.5 centimeters in length, was resected, and suture was carried out with the knee flexed to an angle of 120 degrees.

On January 23, 1942, re-exploration because of absence of signs of recovery. It appeared that the postoperative stretching had produced another traction lesion of even greater severity than that for which the first operation had been performed; two small biopsy specimens taken from the nerve trunk showed nothing but fibrous tissue presenting an appearance like that of tendon.

March 11, 1942 (eight and a half months after nerve suture), resection of the fibrotic zone, which was 19 centimeters in length, was done. The gap was bridged with a homograft, removed 30 minutes previously from a freshly amputated leg. The condition for which the amputation was performed was sarcoma of the tibia and the lateral popliteal nerve was used, with the result that a very good fit was obtained. The blood group of the donor was O; that of the recipient B.

April 2, 1942, soldier returned home wearing a toe-raising spring.

October 5, 1943, a firm cord was palpable in the line of the lateral popliteal nerve from above the knee joint to below the head of the fibula. It was not tender and neither pressure nor percussion over the nerve gave any sensations referable to its distribution. No signs of recovery were noted, although ample time had been allowed for regeneration—573 days for 20 centimeters, the distance between the upper suture line and the nearest muscle, tibialis anterior.

November 19, 1943, operations were done as follows: (1) exploration and removal of lateral popliteal homograft, (2) tenodesis of tibialis anterior and peronei for foot-drop.

The state of the nerve and of the graft:

The proximal trunk had a diameter 10 by 7 millimeters; consistency normal; it ended in a neuroma 20 millimeters long and with a diameter of 13 by 8 millimeters, of much the same consistency as the nerve.

The graft appeared remarkably healthy and shelled out of its bed very easily except at the suture lines where it was moderately adherent (Fig. 1). The diameter of the proximal 7 centimeters, 8 by 7 millimeters; slightly firmer than normal. Below 7 centimeters it split into two parts (see Fig. 1), a large lateral strand 3 by 6 millimeters in diameter and a small medial strand, diameter 2 by 3 millimeters, consisting of three bundles. This part of the graft was soft and "felt empty." At the lower suture line the strands united again and joined the peripheral stump which divided almost immediately into the anterior tibial and musculocutaneous divisions.

Closer inspection of the graft showed that the bundles were easily visible, particularly in the distal part where it was soft; here the sheath was very thin. It was difficult to be certain of its color because of slight persistent oozing from the surrounding tissues; but the nerve looked very like a tendon that had lost its normal sheen,—it had lost the characteristic cream tinge of normal nerve.

Electrical stimulation was entirely negative. The whole of the graft with the adjoining central and peripheral stumps was excised.

Histological appearances. The graft was grossly abnormal in structure, the nervous tissue within it having been replaced almost completely by dense masses of mature collagen. At many points remains of the original nerve bundles were to be seen; in some of these the general architecture was still preserved, but the fibers were necrotic and acellular (Fig. 2); in others the bundles had been invaded by phagocytes, and their nervous tissue partly or completely replaced by collagen (Fig. 3).

This graft, which had been left in place longer than those in Cases 3 and 4, may be taken as showing the later stages in the replacement of a homotransplant: it was almost completely converted into a cable of fibrous tissue, entirely devoid of regenerating nerve fibers at any point, and incapable of receiving them.

CASE 2 (M. 24). R.A.F. officer, born 1908. September 26, 1940, he suffered a violent adduction injury of the left knee while playing a game called "high-cock-a-lorum." On June 30, 1941 he was admitted to the Wingfield-Morris Hospital. Lateral popliteal paralysis was present and there was no evidence of recovery. On July 9, 1941 suture of lateral popliteal nerve which was found to be completely ruptured, both stumps showing considerable intraneural damage. Gap after resection back to satisfactory bundles in both stumps was 15 centimeters. Suture was done with knee flexed 130 degrees and hip in hyperextension. Since, after 8 months, there was no recovery after this suture, which lay just above the head of the fibula, it was decided to re-explore the nerve, and this was done on March 25, 1942. As in the last case it was found that the postoperative stretching had produced a severe traction lesion so extensive that 12 centimeters of completely fibrotic nerve had to be removed before obvious bundles were reached. The gap was bridged with a homograft (the medial popliteal nerve), 16 centimeters long, removed from a leg amputated 14 days previously for osteogenic sarcoma of the tibia, and stored in Ringer's solution in an ice-box in the interval. Blood group of donor A_2; blood group of recipient unfortunately not determined. April 10, 1942 discharged.

When examined exactly 1 year later there was no evidence of recovery that could not be attributed to circumferential overlap. Later in the same year it was learned that this officer had been killed in an accident on October 14, 1943, so there is no information about what recovery, if any, occurred between March and October. But there was no clinical evidence after 365 days that any fibers had reached the most proximal muscle, the tibialis anterior, lying 21 centimeters from the proximal suture line.

CASE 3 (B. 36). A soldier, born 1914. November 12, 1941, he suffered a fracture of the right humerus with a most unusual combination of nerve lesions; there was incomplete radial paralysis, complete paralysis of biceps and brachialis but no loss of sensibility in the cutaneous distribution of the musculocutaneous nerve, and complete median paralysis. March 11, 1942, he was admitted to the Wingfield-Morris Hospital. March 25, 1942, exploration of median nerve and bridging of gap by a homograft.

The lesion was a remarkable one. The proximal trunk of the median nerve terminated in a large neuroma whose lower extremity was 2 centimeters below the junction of the roots of the nerve. This neuroma was connected by a fine strand of tissue about 1 millimeter in diameter and 13 centimeters long with the distal trunk, which ended proximally in a conical glioma. Direct repair was out of the question especially as the gap after resection back to satisfactory bundles was 19 centimeters in all. The gap was bridged with a homograft, the lateral popliteal nerve, removed from a leg amputated 14 days previously for osteogenic sarcoma of the tibia, and stored in Ringer's solution in an ice-box, in the interval. Blood group of donor O; blood group of recipient O.

May 24, 1943, no sign of recovery; the distance between the proximal suture line and the nearest muscle, pronator teres, was 27.5 centimeters, and this muscle was still paralyzed after 425 days. It was, however, possible that regeneration was proceeding very slowly and it was, therefore, decided to explore the nerve under local anesthesia, with a view to detecting sensory fibers by direct electrical stimulation. The operation was carried out on the following day.

The state of the nerve and of the graft:

There was dense scar tissue surrounding the whole track of the graft, but particularly at its upper and lower ends; it appeared that the graft itself was not adherent to the scar though the subsequent histological examination suggests that the line of cleavage was rather artificial. The central and peripheral stumps presented no unusual features (Fig. 4) but the graft had shrunk from 19 to 12 centimeters in length and from 7 to 2.5 millimeters in diameter, except at its extremities where it gradually broadened out until it blended with the central and peripheral stumps. It was impossible to estimate the consistency of such a fine strand with any certainty.

Fig. 1. Case 1. Appearance of the graft 573 days after implantation. Proximal end on right.

Electrical stimulation was entirely negative and as it was obvious that the graft had almost disappeared it was excised without hesitation.

Histological appearances. Examination of transverse sections of the graft at various levels showed that the great shrinkage which it had undergone was due to removal of nerve substance, and not to a shrinkage of the tissue elements themselves. Thus at several levels the specimen had a diameter of only 2 by 1 millimeter, and it contained only one nerve bundle, 1 by 1 millimeter in diameter. This remaining nerve bundle was not in any way shrunken (Fig. 5). It contained a large number of nerve fibers

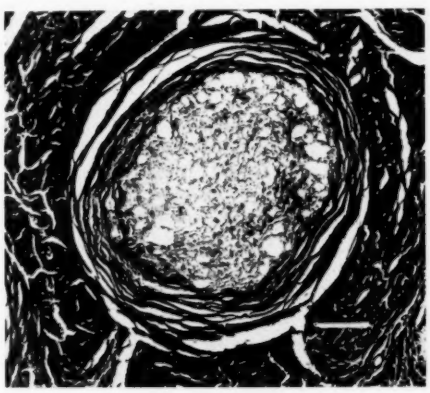


Fig. 2. Case 1. A completely necrotic nerve bundle. Masson. Scale = 100 μ.

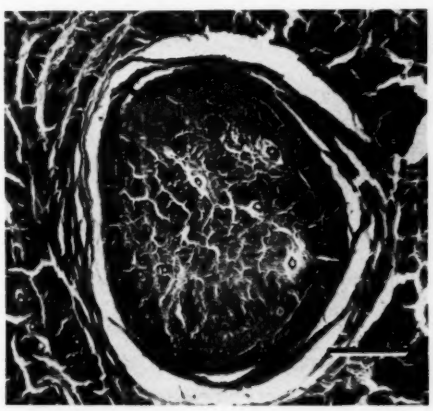


Fig. 3. Case 1. A nerve bundle which has been transformed into a mass of collagen. Masson. Scale = 100 μ.

Fig. 4. Case 3. Appearance of the graft 425 days after implantation. Its diameter has decreased by about two-thirds.

which retained their general normal architecture (Fig. 6), but were completely necrotic, being devoid of nuclei of any kind and abnormal in staining reactions. At several levels in the graft these areas of preserved necrotic fibers were bounded by zones of active phagocytosis, in which the necrotic fibers were in the process of destruction: the regions in which this process was complete were filled with dense masses of collagen (Figs. 5 and 6).

At the extreme ends of the graft its replacement was still further advanced: the specimen consisted entirely of dense fibrous tissue containing only 1 or 2 minute fibrotic nerve bundles (Fig. 7).

In this case, therefore, the grafted nerve did not survive, and the donor nervous tissue was in the process of replacement by a mass of collagen fibers. This replacement was furthest advanced at the ends of the specimen, and the great shrinkage in the middle of the graft was due to the fact that only one nerve bundle remained; the collagen which had replaced the rest of the nerve was presumably adherent to the host tissues, and was dissected away during operative exposure.

CASE 4 (B. 46). A school-boy, born 1929. September 25, 1941, boy received injury to left arm while out rabbit shooting; there was extensive loss of tissue in the lower half of the medial aspect of the arm. The wound was treated without delay and healing was expedited by skin grafting. Some days after the injury it was noticed that there was some involvement of the median and ulnar nerves.

On June 9, 1942, he was admitted to the Wingfield-Morris Hospital. He had a deep irregular scar on

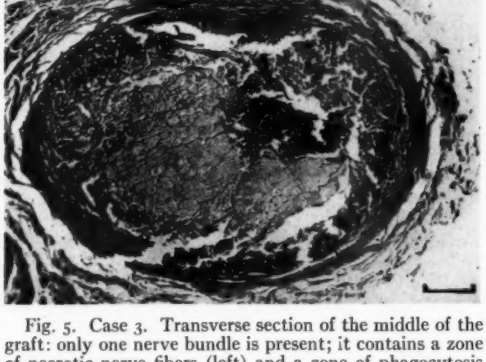


Fig. 5. Case 3. Transverse section of the middle of the graft: only one nerve bundle is present; it contains a zone of necrotic nerve fibers (left) and a zone of phagocytosis and collagen replacement (right). Masson. Scale = 100 μ.

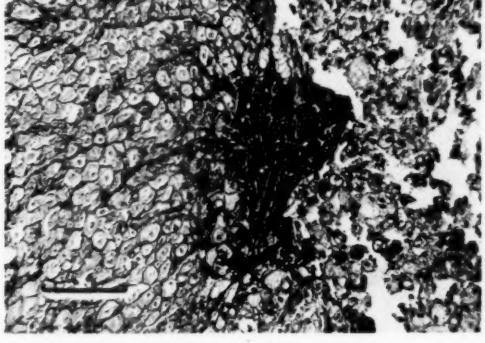


Fig. 6. Detail of part of the graft showing a condition similar to that in Figure 5. Masson. Scale = 100 μ.

the medial side of the arm, 11 centimeters long by 6 centimeters broad, ending 2 centimeters above the medial epicondyle. Healing had been complete since November, 1941. There was complete ulnar paralysis. Median nerve: all forearm muscles acted strongly though there was no response to galvanic or faradic stimulation; paralysis of intrinsic muscles of the thumb, anesthesia of median distribution but some sweating in the palm and analgesia only in the anhidrotic patches. No further details will be given about the median nerve since they are hardly relevant.

June 17, 1942 exploration of median and ulnar nerves was carried out; homograft used to bridge the gap in the latter. There was a gap in the ulnar of 11.5 centimeters. This was reduced to 8 centimeters by anterior transposition of the distal stump and sacrifice of the branches to the long flexors; but as a total resection length of 3 centimeters was required for exposure of healthy bundles proximally and distally the gap to be bridged even with the elbow flexed at 90 degrees was about 11 centimeters.

It happened that a long strand of the medial cutaneous nerve of the forearm, diameter 2 by 3 millimeters was available in a case undergoing operation in an adjoining theater and this was used to bridge the gap. At the suture lines the bed for the nerve was satisfactory but in the intervening zone the muscle beneath and the overlying subcutaneous tissues were both densely scarred. Blood group of donor O; of recipient A.

June, 1943. Although insufficient time had elapsed for clinical manifestations of recovery (the branches to the long flexor muscles having been sacrificed) it was decided to re-explore the nerve in view of the disquieting state of affairs found in Case 3 and the manifestly unsatisfactory dimensions of the graft, which was much too small in diameter.

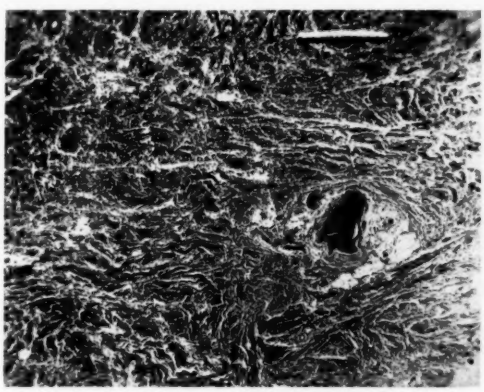


Fig. 7. Case 3. Transverse section of the graft immediately below the proximal suture line. Only one tiny fibrotic nerve bundle remains; the rest is fibrous tissue. Masson. Scale = 400 μ.

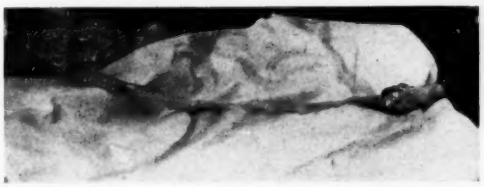


Fig. 8. Case 4. Appearance of the graft 371 days after implantation.

June 23, 1943, exploration of ulnar nerve and resection of graft were done. The dissection was difficult on account of scarring.

The state of the nerve and of the graft:

The central stump ended in a hard neuroma and there was a soft glioma on the peripheral stump. The graft was of about the same length as at the time of insertion, namely 12 centimeters, but its diameter was reduced by about one-half (Fig. 8). In view of this shrinkage it was decided that the graft was serving no useful purpose and it was removed together with the adjoining central and peripheral stumps.

Histological appearances. The longitudinal sections of the proximal suture line showed that, as the macroscopic appearances suggested, the host nerve terminated in a bulbous neuroma, containing nerve fibers of all sizes. The grafted nerve was closely apposed to the end of this neuroma, and at its proximal end some apparently normal nerve bundles contained numerous regenerating nerve fibers; in these bundles the Schwann cells were proliferated, and over the proximal 5 millimeters of the graft they had the usual appearance of nervous tissue which has undergone Wallerian degeneration and is in the process of reinnervation (Fig. 9). But around and within these bundles masses of lymphocytes were seen, and large numbers of dilated blood vessels and vessels devoid of corpuscles which may have been lymphatics; these signs of chronic inflammation could hardly have been due to the suture material used, since they were quite remote from it.

At a level about 8 millimeters below the suture line the graft bundles began to show even more marked abnormalities of structure, and contained very few regenerating fibers. And at 25 millimeters below the suture line they had lost all trace of normal nerve tube structure, and were composed only of dense masses of collagen, in which a few abnormally shaped cells, perhaps phagocytes, were scattered. No identifiable Schwann cells were present, and the interfascicular connective tissue contained masses of lymphocytes and some multinucleated giant cells. And in the middle of the graft there was only a trace of even the general appearance of nervous structure, for the specimen was chiefly composed of a mass of scar tissue (Fig. 10). Great abnormalities were visible throughout the distal half of the graft. Some nerve bundles contained masses of phagocytes in process of removing the remains of the original nerve

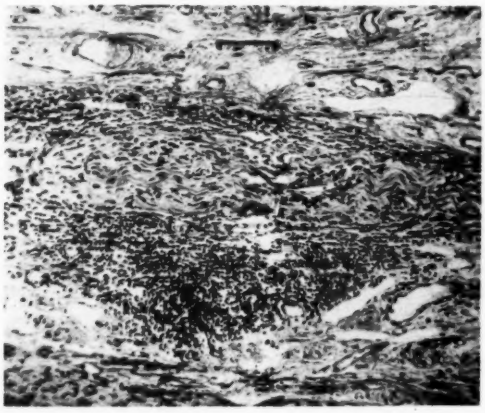


Fig. 9. Case 4. Longitudinal section of a nerve bundle in the graft immediately below the proximal suture line: it contains normal proliferated Schwann cells, but there is an intense local lymphocyte reaction and many dilated vessels around and within the bundle. Masson. Scale = 100 μ.

fibers, and others contained only masses of poorly nucleated collagen (Figs. 11, 12 and 13). These abnormalities became less marked as the distal suture line was approached, but here also there were all the signs of an intense chronic inflammatory reaction.

Thus although the nervous structure of the graft was reasonably well preserved over a length of a few millimeters at its extremities, and had been invaded by regenerating axons, an intense inflammatory reaction had been provoked, and most of the transplanted nerve was in the process of phagocytic destruction and collagen replacement.

OBSERVATIONS

Three of these homografts were unqualified failures, and there is little reason to suppose that success might have been achieved in Case 2 but for the patient's untimely death. In Case 3 the graft had been stored for 14 days in Ringer's solution, and in some respects the histological changes found within it differed from those in Cases 1 and 4 in which a fresh transplant was used. The stored graft seemed completely dead, like a sequestrum of bone or muscle, and was in process of removal exactly as if it were a foreign body: when inspected 426 days after implantation its diameter had been reduced by more than one half, yet there was no shrinkage of the bundles that remained: the graft had been eaten away. On the other hand, in Cases 1 and 4 there appeared to be a progressive interstitial phagocytosis and replacement of the graft tissues by

Fig. 10. Case 4. Transverse section near the middle of the graft: only a few small and abnormal bundles remain, the rest have been replaced by collagen. van Gieson. Scale = 500 μ.

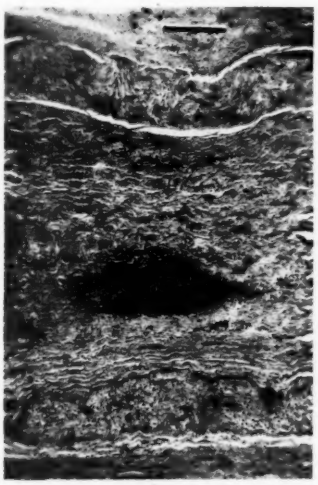


Fig. 11. Case 4. Longitudinal section toward the distal end of the graft. One bundle shows phagocytic removal of the graft nerve fibers, and in the other collagen replacement is complete. A mass of lymphocytes lies in the interfascicular connective tissue. Masson. Scale = 200 μ.

collagen. This difference in behavior may not be significant, but it certainly shows that storage of homografts, which is actually beneficial in rabbit experiments, has no advantage in surgical practice; it also indicates that Wallerian degeneration does not proceed normally in a graft of this size during the period of storage.

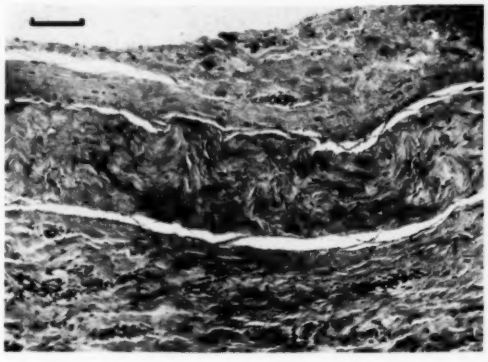
There is, therefore, a most disturbing contrast between the state of these homografts and that described in rabbits (Sanders and Young, 1942; Gutmann and Sanders, 1942). For although the rabbit homografts were invaded by macrophages and lymphocytes, in a manner never seen in autografts, reinnervation proceeded in a more or less orderly fashion. In the late stages the only significant abnormalities were a few patches of fibrosis and a deficiency of larger fibers; functional recovery, though poorer than after autografting, was good enough to be useful. What factors, then, might account for the failure in our cases and the relative success in animal experiment?

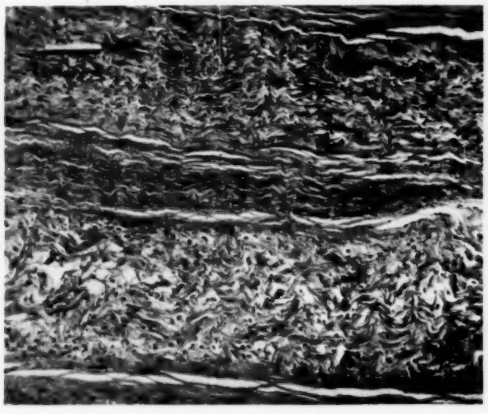
1. *Blood group compatibility.* The discovery of blood groups has been a powerful stimulus to the study of homologous tissue compatibility in general, though it has too readily been assumed that there is some connection between red blood cell compatibility and compatibility of tissues with nucleated cells. The nature of the problem, as it concerns skin grafting, has been discussed by Medawar (1943), who reached the tentative conclusion that the failure of skin homografts is unrelated to blood groups: the evidence brought forward by Gibson and Medawar (1943) suggested rather that the failure is due to the development of an *active acquired immunity.*

And in corneal grafting, which in recent years has been conspicuously successful, the blood groups of donor and recipient are irrelevant (Duke Elder, 1938).

Therefore, one is bound to consider the possibility that the failure of nerve homografts in our series of cases, and in those recorded in the literature, was due to the acquisition by the host tissues of an active immunity to the grafted nerve tissue. If this is so, then the success of homografts in the rabbit, and the recovery in Duel's 3 cases of facial nerve homograft, might be due to the small size of the transplant. The outgrowing host nerve fibers, perhaps accompanied by their own Schwann cells, could traverse the nerve tubes of the graft and reach the peripheral stump, before the destructive reaction was developed.

However, there is not as yet sufficient evidence to lead to the conclusion that blood-group compatibility is irrelevant to the problem of nerve homografting. In Duel's 3 cases the blood groups of donor and recipient were the same, and there is no record in the literature of any series of cases in which the correlation between blood-grouping and the success or failure of the graft is made. In the





Figs. 12 and 13. Detail of the two nerve bundles shown in Figure 11. Masson. Scale = 100 μ.

present state of our knowledge, surgeons who intend to use nerve homografts should no doubt group recipient and donor so that decisive evidence may be forthcoming. But unless some method is discovered for storing grafts without diminishing the prospects of a take (our single experience is not encouraging), the chances of getting a graft from a donor of the same blood group as the recipient will be very remote, since they depend on the coincidence of a nerve exploration requiring a graft with an amputation for an uninfected lesion, neither very common occurrences, in patients of the same blood group. If blood groups matter, then storage is essential.

2. *The thickness of the graft.* It has been suggested here that the success of small homografts in animals and man may be due to the fact that satisfactory innervation can take place before an immunity reaction develops in the host tissues. If this is so, then the failure of large grafts in man is due to their length, and perhaps to some extent to their mass as related to the total mass of the body. But a simpler explanation may be that the failure is due to inadequate vascularization of the graft. If this is the case, then a cable homograft, having a better chance of rapid vascularization, would be more successful than a graft having the full thickness of a main nerve trunk. In 3 of our cases (2 examined histologically) the grafts were from main nerve trunks, and it is conceivable that there was a delay, a fatal one, in their vascularization. However, in Case 4, in which the graft was from a subcutaneous nerve, an equally depressing state of affairs was found; though it must be conceded that here the bed was a poor one. Yet, if the large grafts necrosed centrally as a result of delayed vascularization, it would be expected that the more peripheral bundles would survive. This was not the case, and failure of blood supply can hardly be held responsible for the destruction of the graft.

3. *The state of the suture lines.* Although the state of the suture lines is of supreme importance, the most satisfactory union is of no avail if the substance of the graft undergoes unfavorable changes. In our cases the approximations obtained at the grafting operation were as good as those performed in the average end-to-end suture; the macroscopic appearances at the later explorations and the histological findings showed that there had been no rupture of the suture line or other accident.

Our short series of cases does not yield sufficient evidence for an analysis of the nature of the process responsible for the destruction of the nerve homografts. The fate of the stored graft might be simply described as that of an implanted foreign body, but the replacement of the fresh homografts is a more obscure process. A remarkable feature is the preservation of the general macroscopic structure of the graft in spite of the profound internal changes which it has undergone. This preservation might be taken to suggest that it is the fibroblasts of the transplant itself which proliferate in the process of collagenous replacement, though it would seem more reasonable to suggest that they are cells of host origin. Eden, as heretofore stated, temporized by suggesting that cells of both types took part in the process.

But there is no doubt that the reaction, at least in its end-result, is very different from that found in rabbits or cats (Bentley and Hill, 1936), though the difference may be one of degree rather than of kind. The results of animal experiment have been not uninformative so much as actually misleading, and the proper study of homografts, so far as clinical surgery is concerned, must be in man. The difficulty of the problem is that of collecting evidence; assuming that further clinical trials are worth while (and there is little to encourage us in this belief), the factors governing success or failure could hardly be discovered without numerous biopsies, to which even the most co-operative patient could not possibly be asked to submit. Experiments on large animals might, perhaps, bring us reasonably near to a final answer.

SUMMARY

1. Although the results of nerve homografting in small animals are not discouraging there is evidence that the implanted tissue almost invariably provokes a cellular reaction

which, since it may lead to more or less collagenization within and around the graft, must be regarded as unfavorable.

2. In man there are apparently only 3 recorded successes after homografting and in each case the facial, a very small nerve, was repaired. There is so far only 1 published record of the late appearances of a human nerve homograft: it had become completely converted into a strand of fibrous tissue (Eden).

3. Four cases of human homografts are reported in this paper, all of them failures, and in 3 the remains of the graft were examined at 371, 425, and 573 days, respectively. In 2 cases in which fresh grafts were used the bulk of the graft had become collagenous to such an extent that almost nothing remained of the original nerve elements, and there was clearly no sign or even possibility of regeneration through this long core of fibrous tissue. In the case in which the graft used had been stored for 14 days in Ringer's solution, the tissue was completely dead and was in process of removal by phagocytosis.

4. The following possible causes of failure are discussed: (a) Blood group incompatibility; an unproved and improbable factor. (b) The development of a specific tissue immunity such as seems to be responsible for the destruction of skin homografts. Where the gap to be bridged is short, as in rabbit experiments, the reaction may not occur until after fibers have reached the peripheral stump; on the other hand, in man the gap to be bridged is always a long one and it may well be that an immune reaction attains its greatest intensity long before the fibers have had time to traverse the graft. (c) Failure of vascularization; almost certainly of no significance.

5. Thus, although the available evidence is not great, it all tends to show that nerve homografting as a means of closing large gaps is an unsound procedure.

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THE ESTIMATION OF AREAS OF BURNS

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ALTHOUGH the proportionate area of skin burned has long been recognized as useful as a guide to the prognosis of burns, the proportionate area has now become of even greater importance as a guide to treatment. One of the first needs of a patient with a serious burn is adequate plasma therapy. After a close estimate of the size of the area of the burn and of its proportion to the total area of skin has been made, the "First-aid Formula" (5) can be used to estimate the approximate amount of plasma needed during the first day of treatment. The exact amount to be given should, however, be guided by repeated tests of the hemoglobin, hematocrit, or red blood count, and of the plasma protein and other chemical tests of the blood.

Long prior to its use for this purpose, Weidenfeld and Berkow made studies directed to simplifying the recording of and comparison of burns. Both studied by actual measurement the surface areas of the parts and of the whole surface of many individuals of all ages. As a result of this work, in this country and in Great Britain, "Berkow's table" is constantly in use in studies of burns. Both Weidenfeld and Berkow pointed out that surface proportions varied widely between birth and adult life. Seeger and Wallace also pointed out this fact, but other important publications that have stressed the use of Berkow's table have mentioned only his table for adults.

When in search of a suitable diagram and standards for the recording of burns in children it was seen that Berkow's tables for adults and for children, which have been perfectly satisfactory for work up to date, are oversimplified and contain certain errors that should, if possible, be avoided in the more exact studies that are now being made in many clinics. For instance, he used DuBois and DuBois (4) measurements to determine the areas of the different parts of the body and found the same values for the parts that DuBois and DuBois found. These measurements include the buttocks with the trunk. But, without making a counterbalancing correction in the figures, Berkow includes them with the thighs. Furthermore, he set a higher value on the trunk than either DuBois and DuBois or he, himself, had found to be an average measurement and made the following explanation. "To balance the greater seriousness of burns of the anterior surface of the trunk, the third and fourth decimal places have been deducted from the average proportions of the head and extremities and added to the number expressing the proportion of the trunk. This gives the trunk a value of 38% of the body surface; and of this 20% is apportioned to the anterior surface and 18% to the posterior."

From the Burn Assignment of the Surgical Services of the Boston City Hospital and the Department of Surgery, Harvard Medical School. The work described in this paper was done under a contract recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Harvard University.

LITERATURE

The literature concerning the surface area of the body consists of the two articles previously mentioned (1, 11) and many articles by authors primarily concerned with problems of the measurement of basal metabolism. Boyd has summarized this literature in a very useful manner. A difficulty arises, however, in that all the data assembled for metabolism work had been collected primarily to secure a correct total area, and differences in points of division between one region and another were unimportant in securing a valid total. In the use to which surface area proportions are put with burns, such definitions are of great importance. Also it is of great importance to subdivide the surface into as many clearly demarcated areas as possible so as to permit the easiest possible visual comparison. A large amount of excellent information is available in Boyd's monograph to permit the divi-

sion of the body surface into 12 parts (head, trunk, and two each of thighs, legs, feet, arms and forearms, and hands). The data for subdividing the upper extremity into three, instead of two, parts and for separating the neck, buttocks, and genitalia from the trunk, are less ample but sufficient for the estimation needed. There are no data on the relative proportions of the anterior versus the posterior parts of the trunk.

LINES OF DEMARCATION OF MAJOR REGIONS

Lines of demarcation of some regions were summarized by DuBois and DuBois (4) as follows:

"Head—Lower margin of the mandible to its posterior border, thence to tip of the mastoid process and in a straight line to the external occipital protuberance.

"Arm—From the acromion process anteriorly and posteriorly to the upper border of the axilla.

"Hand—Line at right angles to long axis of forearm drawn at level of tip of ulna.

"Thigh—From the perineal point going posteriorly in the natal fold to the upper border of the great trochanter, thence medially in a straight line to the perineal point.

"Leg—Line at level of lower border of patella.

"Foot—Line at level of tip of lateral malleolus."

These lines are strictly followed in this paper. Other lines are defined as follows:

1. *Neck.* The line of demarcation between the neck and the trunk is the shortest line from the supraclavicular notch to the spinous process of the 7th cervical vertebra.

2. *Elbow.* The arm is separated from the forearm by a line drawn from the upper edge of the olecranon around to the antecubital fold.

3. *Buttocks.* The lower edge of the buttocks has been defined as noted by DuBois. The other edges are defined as included by a line vertical from the upper posterior corner of the trochanter to the point where it meets the crest of the ilium, then posteriorly to the midline of the sacrum and down the sacrum to the perineal point.

4. *Genitalia.* The areas defined as genitalia are the penis and scrotum in males, and the labia in females, the latter are considered to extend from the perineal point to the upper edge of the pubic bone.

5. *Anterior and posterior trunk.* Lateral to the neck, as has been defined, the anterior and posterior halves of the trunk are divided by a line along the anterior edge of the trapezius muscle. Below the axilla they are divided by a vertical line from the midaxilla.

CHANGES OF PROPORTIONATE AREA OF REGIONS WITH AGE

At birth the size and area of the head is very large and the size and areas of the legs very small compared to their proportions in adult life. Ample data of excellent quality are available to show the changes during the child's development. It is of interest that the body and arms change their proportions very little during development. After the age of 20 years, further age, *per se*, results in no change of any magnitude to any part of the body.

TABLES OF PROPORTIONATE AREAS OF PARTS OF THE BODY

Boyd has constructed a table giving the results of calculations made from the most accurate data available in the literature concerning the changes in area during growth. This table divides the body into four major areas. In her publication it includes monthly data on fetuses from the third solar month to term and yearly data on living humans from 1 year to 24 years. Certain items from this table are reproduced in Table I. The data for newborn are from the Klein Scammon study of fetuses.

TABLE I.—PERCENTAGES OF SURFACE AREA OF THE MAJOR DIVISIONS OF THE BODY ACCORDING TO BOYD*

Age	Head	Trunk‡	Upper extremities	Lower extremities
0	21	32	17	31
1	17	34	18	31
5	13	33	20	34
10	11	34	19	36
15	9	32	21	38
24	8	35	19	39

*Data from Boyd (2) p. 119, decimals omitted. Boyd gives the actual measurements as well as the percentages.
‡Includes neck, genitalia, and buttocks.

Berkow's formula for calculating the surface proportions of children is a simple one. He takes his proportions for adults as a starting point. These are: head, 6 per cent; trunk, 38 per cent; upper extremities, 18 per cent; and, lower extremities, 38 per cent. For children of all ages he leaves the percentages for the trunk and upper extremities the same. He adds to the head 1 per cent for each year the

age is below 12 and subtracts the same number from the figure for the lower extremities. By using this formula, Table II has been constructed.

TABLE II.—PERCENTAGES OF THE SURFACE AREA OF THE PARTS OF THE BODY ACCORDING TO BERKOW

Age	Head	Trunk*	Upper extremities	Lower extremities‡
0	18	38	18	26
1	17	38	18	27
5	13	38	18	31
10	8	38	18	36
15	6	38	18	38
Adult	6	38	18	38

*Includes neck and genitalia.
‡Includes buttocks.

The figures in Table II correspond exactly with those in Boyd's table in many items and partly in others. The most serious discrepancy is caused by the systematic errors introduced by Berkow which result in much too high proportions being assigned to the body and too low to the lower extremities. As Berkow states, the buttocks should be included with the legs, but since he used a method of measurement that did not accomplish this result, 5 per cent should be added to his figures for the trunk and subtracted from the lower extremities for a proper comparison with Boyd's data. The effect on the estimated area of the trunk of making this correction results in a value of 43 per cent which is a value one-third larger than Boyd's figure at the age at which the difference is greatest (15 years) and one-quarter larger at the age with the least difference (24 years).

Boyd's table would be difficult to use in clinical studies of burns because it contains more small changes than are necessary for this type of work. Berkow's principle of keeping the same value at all ages is very useful, if too great an error can be avoided. Therefore, a new table has been constructed that approaches closely to Boyd's figures at all ages above birth and avoids the extreme errors of Berkow's.

Some difficulty was encountered in making a decision as to the best figures for newborn infants. Boyd's figures for this age are based on the data of Klein and Scammon of the surface area of fetuses. However, there are records of three living newborn infants, two calculated by Berkow and one by Meeh. Their measurements give slightly smaller percentages to the areas of the head and lower extremities and larger ones to the areas of the trunk and the upper extremities. For the new table, the average data of these three records were used as the chief criterion of the percentage area of the parts of newborn infants after correcting for Berkow's inclusion of the buttocks with the legs (Table III).

TABLE III.—NEW TABLE OF SURFACE PROPORTIONS FOR USE IN STUDY OF BURNS

Age-Years	Head	Trunk*	Upper extremities	Lower extremities
0	19	34	19	28
1	17	34	19	30
5	13	34	19	34
10	11	34	19	36
15	9	34	19	38
Adult	7	34	19	40

*Includes neck, genitalia, and buttocks.

DETERMINATION OF AREAS OF SUBDIVISIONS

Neck. A close estimation of the area of the neck may be made because Bradfield and Boyd both made measurements and calculations on the same subjects by two or more methods, one of which included the neck with the head and the other with the trunk. The difference in results is such that 2.4 is the area of the neck in young women, 2.0 in 16 and 17 year old girls, and 2.5 in 3 to 5 year old children. Here it will be considered to be 2 per cent.

Genitalia. From data in Boyd that are old and rather fragmentary, the area of the genitalia has been stated to be from 1 to 2½ per cent. These figures are quoted without definitions. By comparison with the area of the hand, it would seem reasonable to place a figure of 1 per cent for these areas.

Buttocks. There are no modern data on the buttocks as a separate area. Again by comparison with the hand it can be seen that the area of the buttocks as defined is close to 5 per cent (for the 2).

Anterior and posterior trunk. After the three subdivisions mentioned are deducted there is 26 per cent of area left for the trunk. The dividing lines described separate the trunk into anterior and posterior parts that are very nearly, if not exactly, equal in area. Therefore 13 per cent is indicated as a suitable figure for each.

Hands. A large amount of information is available concerning the area of the hands. All the data at all ages place the area of them as either exactly or very close to 5 per cent. This is a very useful figure to know in measuring burns because by using one side of one hand of the patient as an estimating device it is very simple to get an approximation of the number of times the burn is larger than this area. For this purpose the area of one side of the hand, (and closed fingers) has frequently been considered to be 1 per cent. There is no discrepancy between this value of 1 per cent and the total value of 5 per cent because the latter includes skin on the sides of the hand and between the fingers.

Forearms. Much information is available for the area of the arms as a whole, separate from the hands but rather less for the arms and forearms separately. However, the data available are consistent and almost certainly reliable. A suitable estimate for the two forearms is 6 per cent.

Arms. By subtracting the areas of the hands and forearms from that of the upper extremities given it is seen that 8 per cent is the surface of the two upper arms. This value is consistent with the measurements available.

Feet. Although the areas of the lower extremities vary with age, that of the feet do not. There are ample data to show that 7 per cent is the average area of the feet.

Legs. As the legs vary with age it is fortunate that many measurements of the legs and thighs have been made separately. The two legs start at birth with 10 per cent of surface area. At 1 year of age there is no change. At 5 the figure is 11 per cent, at 10 it is 12 per cent, at 15, 13 per cent, and in adult life, 14 per cent.

Thighs. The thighs grow more rapidly than the legs. They are 11 per cent at birth, 13 per cent at 1, 16 per cent at 5, 17 per cent at 10, 18 per cent at 15, and 19 per cent in adult life.

Table IV is constructed from these data.

TABLE IV.—NEW TABLE OF SURFACE PROPORTIONS IN DETAIL

Age	Birth	1	5	10	15	Adult
Area						
Head	19	17	13	11	9	7
Neck	2	2	2	2	2	2
Anterior trunk*	13	13	13	13	13	13
Posterior trunk‡	13	13	13	13	13	13
Buttocks	5	5	5	5	5	5
Genitalia	1	1	1	1	1	1
Upper arms	8	8	8	8	8	8
Forearms	6	6	6	6	6	6
Hands	5	5	5	5	5	5
Thighs	11	13	16	17	18	19
Legs	10	10	11	12	13	14
Feet	7	7	7	7	7	7
Total	100	100	100	100	100	100

*Without neck or genitalia.
‡Without neck or buttocks.

For use in clinical studies, two charts have been constructed for recording the areas of individual cases. On the diagrams are printed the percentages of each area as visualized when the area is fixed at each age. At the bottom are the figures for the varying areas. The chart with the adult figure is used for ages 7½ years and up, and the one with the child's figure for younger children. The two charts (Figs. 1 and 2) are printed on both sides of one piece of paper. In any one case only the side suitable for the patient's age is used.

CHANGES ASSOCIATED WITH ABNORMAL BUILD

From the earliest studies on surface area it has been recognized that differences in body build result in differences in the relative area of different parts of the body. The surprising fact is that except for the changes during growth, these differences in proportion are relatively small unless the differences in build are very gross. For instance, Woerner measured a woman before pregnancy and at term. Her height was 5 feet 1 inch and her weight increased from 130 to 135 pounds. Her total surface area increased 4 per cent, with all of this gain limited to the trunk. The result was an increase in trunk proportions of only 3 per

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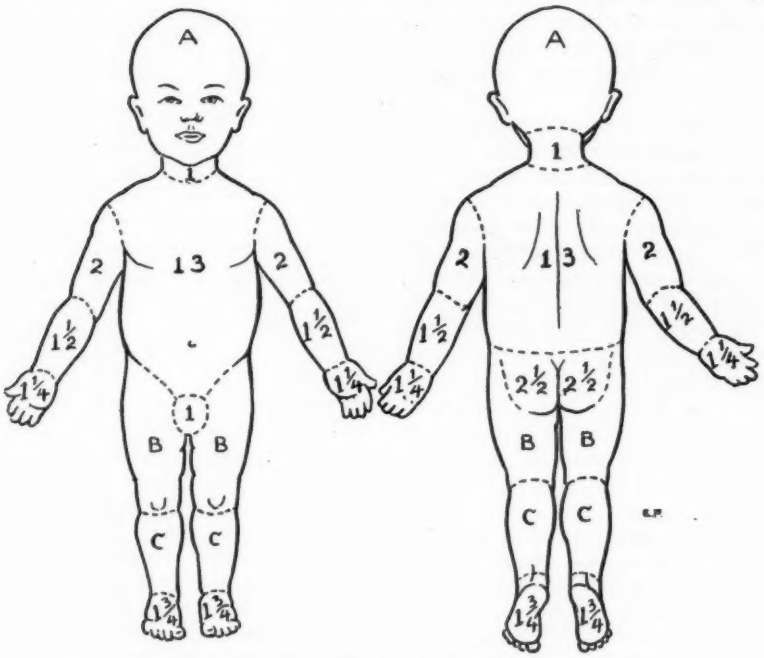
Name ..... Age ..... Number .....

Burn Record. Ages—Birth—7½. Date of Observation .....



RELATIVE PERCENTAGES OF AREAS AFFECTED BY GROWTH

Area	Age 0	1	5
A = ½ of Head	9½	8½	6½
B = ½ of One Thigh	2¾	3¼	4
C = ½ of One Leg	2½	2½	2¾

% BURN BY AREAS

Probable 3rd° Burn	Head	Neck	Body	Up. Arm	Forearm	Hands .....
	Genitals	Buttocks	Thighs	Legs	Feet	
Total Burn	Head	Neck	Body	Up. Arm	Forearm	Hands .....
	Genitals	Buttocks	Thighs	Legs	Feet	

Sum of All Areas Probably 3rd° ..... Total Burn .....

Fig. 1. *Over for Older Patients*

cent (from 35 to 38 per cent) and a decrease of approximately 1 per cent each in the proportions of the upper and lower extremities and of less than ½ per cent in the proportions of the head and neck.

DuBois and DuBois measured a woman with great obesity. She was 4 feet 11 inches tall and weighed 203 pounds. Compared to normal individuals measured by the same methods her trunk made up 42 per cent of her total area instead of 36 per cent. The arms were 12 instead of 14 per cent and the hands, legs, feet, and head each approximately 1 per cent below normal. The thighs remained normal. As different obese individuals differ in the distribution of their excess fat, other over-

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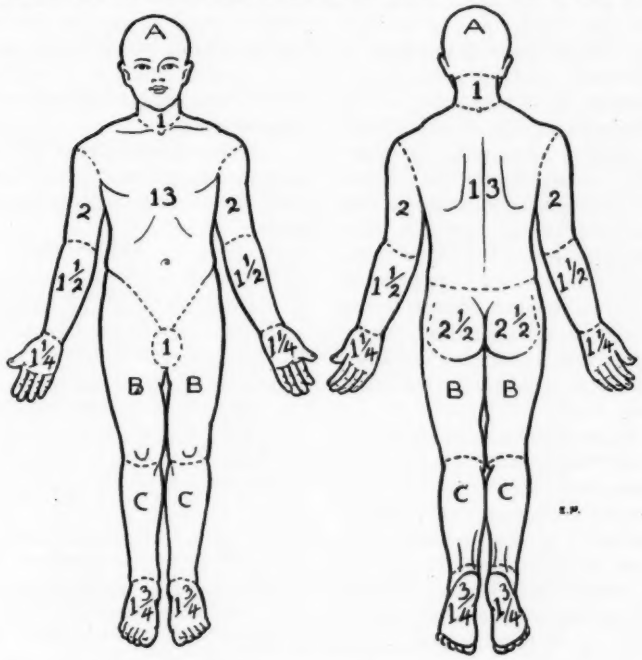
Name ..... Age ..... Number .....

Burn Record. Ages 7½ to Adult. Date of Observation .....



RELATIVE PERCENTAGES OF AREAS AFFECTED BY GROWTH

Area	Age 10	15	Adult
A = ½ of Head	5½	4½	3½
B = ½ of One Thigh	4¼	4½	4¾
C = ½ of One Leg	3	3¼	3½

% BURN BY AREAS

Probable 3rd° Burn	Head	Neck	Body	Up. Arm	Forearm	Hands	
	Genitals	Buttocks	Thighs	Legs	Feet		
Total Burn	Head	Neck	Body	Up. Arm	Forearm	Hands	
	Genitals	Buttocks	Thighs	Legs	Feet		

Sum of All Areas ..... Probably 3rd° ..... Total Burn .....

Fig. 2. *Over for Young Children*

weight patients would not necessarily show the same changes in proportion.

It is of interest that emaciation hardly changes the proportions at all. An example of this is case "Gerald S." in Sawyer, Stone, and DuBois (8).

The condition that causes the greatest alteration in proportions is amputation. Sawyer, Stone, and DuBois (8) measured and calculated 2 such patients that had bilateral thigh amputations. Each of these amputations left the patients with only about one-half the original thigh skin and, of course, none for the legs and feet. The proportions in these patients were 51 per cent for the trunk, 26 per cent for the upper extremities, 9 per cent for

the head, and 15 per cent for the remaining short atrophied thighs.

Even a single amputation at the knee makes more difference to the proportions than the case of pregnancy described. As the surface area of one leg and foot is about 10 per cent of the total, their removal, without any change in the size and shape of other parts would make the following alterations, as calculated from the data presented as standard proportions for an adult. Head from 7 to 7.8 per cent, neck from 2 to 2.2 per cent, anterior and posterior trunk from 13 per cent each to 14.4 per cent each, buttocks from 5 to 5.6 per cent, genitalia from 1 to 1.1 per cent, upper arms from 8 to 8.9 per cent, forearms from 6 to 6.7 per cent, hands from 5 to 5.6 per cent, thighs from 19 to 21.1 per cent, remaining leg from 7 to 7.8 per cent, and remaining foot from 3.5 to 3.9 per cent.

In the care of burns certainly less than ½ of 1 per cent of all cases admitted have such irregular body form that these considerations are of importance in estimating the surface area of the individual. If it is important to study such a case carefully his parts should be estimated by using DuBois and DuBois measurements (4) or the very slightly modified measurements of Sawyer, Stone, and Du Bois (8).

SUMMARY AND CONCLUSIONS

1. In studies of burns an easy, accurate method of visual estimation of the percentage of surface area is important. Certain systematic errors of magnitude can occur when Berkow's table for adults is applied to children.

2. A new table and diagrams have been constructed that avoid these and other systematic errors.

3. It is estimated that this table and these diagrams should be applicable, without serious error, to at least 99.5 per cent of all cases of burns.

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THE VALUE OF SYMPATHECTOMY IN THE TREATMENT OF BUERGER'S DISEASE

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BUERGER'S disease is a chronic, recurrent segmental thrombosis of peripheral and visceral blood vessels. It is preceded by a typical migrating phlebitis in 30 to 40 per cent of the cases. The lesions are frequently in the digital arteries or even more terminal segments, but occlusion of major arterial pathways is often seen. It is necessary to exclude all well known causes of sudden or gradual vascular occlusions such as arterial embolism, spontaneous closure of aneurysmal sacs, presenile atheromatosis, and a whole group of specific infections such as typhus, typhoid fever, malaria, scarlet fever, and the rheumatic infections which produce vascular reactions similar if not indistinguishable from Buerger's disease. Transitions to periarteritis nodosa are not uncommon.

In our present state of knowledge it is not even possible to say whether the endothelial reaction leading to thrombosis is on an infectious, a toxic, or an allergic basis, or whether it is primarily due to changes in the blood which result in vasospasm and endothelial proliferation. One thing is certain: sympathectomy does not modify the course of this disease; it is undertaken only for the purpose of improving circulation in limbs in which blood vessels are occluded; obviously, then, the patient who is a candidate for a sympathectomy must demonstrate the presence of an adequate collateral vascular bed and must show that he is in a quiescent stage of the disease, in a state of remission; nor should the disease show too much visceral extension.

PREOPERATIVE STUDIES

When a patient is admitted to the hospital for study, a simple routine is followed to determine his operability. After a moderate dose of barbiturate, the regional sympathetics are blocked with procaine. On the upper extremity a cervical sympathetic block should result in a Horner's syndrome; on the lower extremity the loss of sweating accurately determines the presence and level of sympathetic paralysis. The sympathetic block may be apparent in a few minutes or slowly develop within the next half-hour. While measurements of skin temperature are desirable and can be easily carried out with a small skin thermometer, with some little experience the observer can tell by palpation whether or not the extremity has warmed up sufficiently. As long as sweating is present in the areas under observation, the sympathetic paralysis is incomplete and may have to be repeated. Special attention must be paid to the temperature of each individual finger or toe (Fig. 1); these digits may remain as cold as they were prior to the injection, or their temperature may even drop, in spite of a good rise of temperature in the more proximal parts. *This paradox drop of skin temperature* is very significant; it means that not only will this digit not benefit from sympathectomy, but a rapidly developing gangrene may occur following the operation. With increasing experience it has become obvious that such toes should be amputated immediately following sympathectomy. This combined operation will be discussed later in more detail. If the entire foot or hand remains cold after a successful block, it means that the vascular capacity is very small, that the occlusion is in the terminal arterial bed, and that sympathectomy will not benefit the foot; but it might still allow the performance of a Syme amputation instead of one 7 inches below the knee. Claudication may or may not improve after sympathetic block. In some patients suffering from angiospastic claudication walking ability improved considerably (6). Thus in the case of C. W. (Fig. 1) the patient could walk 150 steps before and 650 steps after para-

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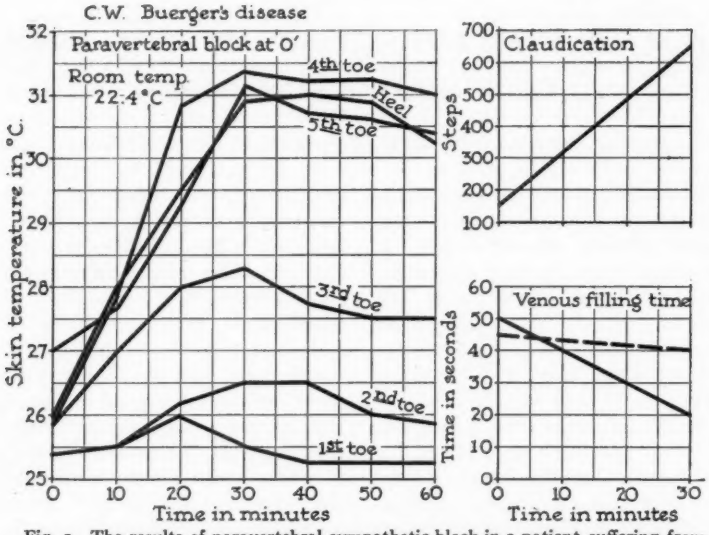

Fig. 1. The results of paravertebral sympathetic block in a patient suffering from Buerger's disease. Graph on left shows the rise in skin temperature of the 4th and 5th toes to the normal vasodilatation level (31°C.). The heel warms up equally well. The 3d toe warmed up from 26 to 27.5°C. The 1st and 2d toes did not warm up at all. Such a patient needs an amputation of his 1st and 2d toes; the 3d toe will remain cold after sympathectomy, but may improve with time. This same patient could walk 650 steps after sympathetic block without getting pain in the calf, against 150 steps before the block. This indicates that angiospasm is a factor in his claudication. The venous filling time (venous filling on the dorsum of the foot after 60 millimeters of mercury pressure was inflated into a blood pressure cuff on the thigh) dropped from 50 to 20 seconds on the injected side; the change on the opposite side from 45 to 40 seconds is within the limits of error. Lumbar sympathectomy with amputation of the first two toes resulted in an excellent anatomic and functional recovery.

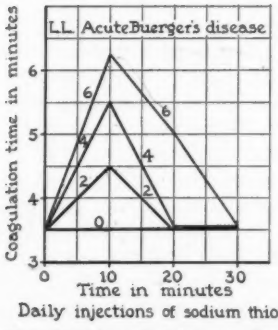

Fig. 2. Improving heparin tolerance of a patient (L. L., Buerger's disease) after daily injections of 0.6 gram of sodium tetrathionate. Numbers indicate the days of medication with the drug. Note that on O day, prior to the injections, the patient's coagulation time could not be raised with 10 milligrams of heparin. With daily injections the response to heparin improves. On the 6th day the patient shows an excellent response. His clotting tendency has been corrected. He is ready for operation.

vertebral block. When such a finding is elicited the patient may be assured of an increased walking ability after sympathectomy.

Venous filling time (1), an excellent method of estimating the decreased rate of flow in an extremity, has been slightly modified. The extremity is elevated until the dorsal veins collapse. With a blood pressure cuff around the thigh or upper arm, a pressure of 60 millimeters of mercury is produced and the limb placed in the horizontal position in a warm room. When the dorsal veins become prominent or show slight pulsation, the veins are considered being filled. From the normal of 5 to 10 seconds, some extremities may show a filling time as slow as 120 to 180 seconds. In the case of C. W., the venous filling time shortened from 50 to 20 seconds, indicating a good response to sympathetic block.

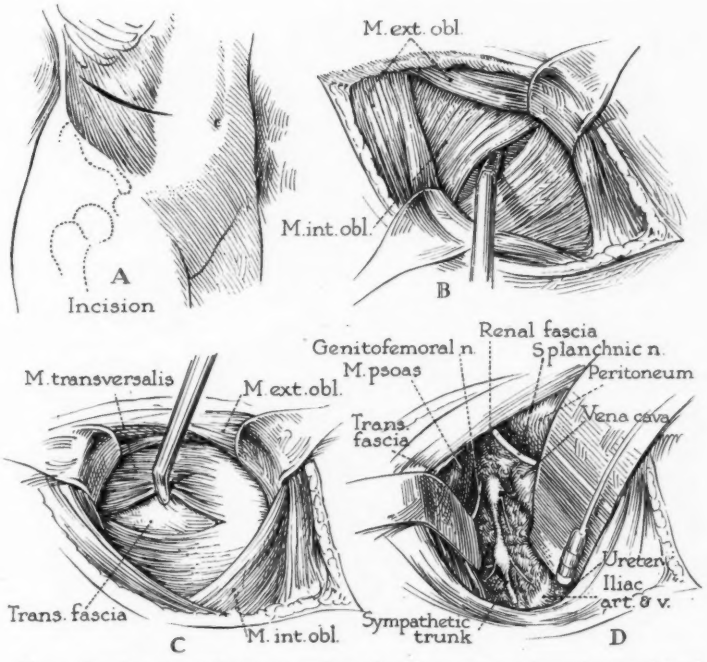

Fig. 3. Lumbar sympathectomy performed with an extraperitoneal anterolateral muscle-splitting approach. A, The incision starts in the midaxillary line, below the 12th rib and extends to the lateral border of the rectus muscle at the level of the umbilicus. B, The external oblique muscle is separated along the course of its fibers; the internal oblique muscle is in the process of separation. In very muscular individuals it may be necessary to cut this muscle parallel to the first layer of muscle. C, Both external and internal oblique muscles are retracted; the transversalis muscle is separated and the transversalis fascia becomes visible. D, The transversalis fascia is widely dissected off the psoas muscle and the sympathetic chain is exposed between the medial edge of the psoas and the vena cava. Dissection may be hampered by lumbar veins traversing the field or by a chain of enlarged lymph glands. Note the genitofemoral nerve which should be carefully protected from vigorous retraction since this may result in annoying paresthesias. The chain is removed from the level of the sacral promontory to the crus of the diaphragm. Closure is made in layers with cotton. The lighted retractors were abandoned several years ago for a head-lamp. Approach of Flothow.

After the capacity of the peripheral vascular bed to dilate when vasomotor tone is removed has been determined the next question is that of the activity of the process. Our group has availed itself of a simple test of the clotting mechanism, the heparin tolerance, which is greatly depressed in patients with active Buerger's disease (2). The normal response of the individual to 10 milligrams of heparin is quite stable. Under certain conditions, some of which have been studied and some of which are still under investigation, the response to heparin is diminished. Buerger's disease in its acute and subacute forms is one of the conditions characterized by a tendency to thrombosis as shown by the heparin tolerance. Since all major operations are followed by a temporary tendency to thrombosis it is important not to operate while patient is in a state of heparin resistance. Earlier, before attention was paid to this phase of the problem, the incidence of postoperative thrombosis after sympathectomy was high, 4 per cent, identical with that of a pelvic laparotomy.

Theis and Freeland, on the basis of extensive chemical studies, advocated the use of

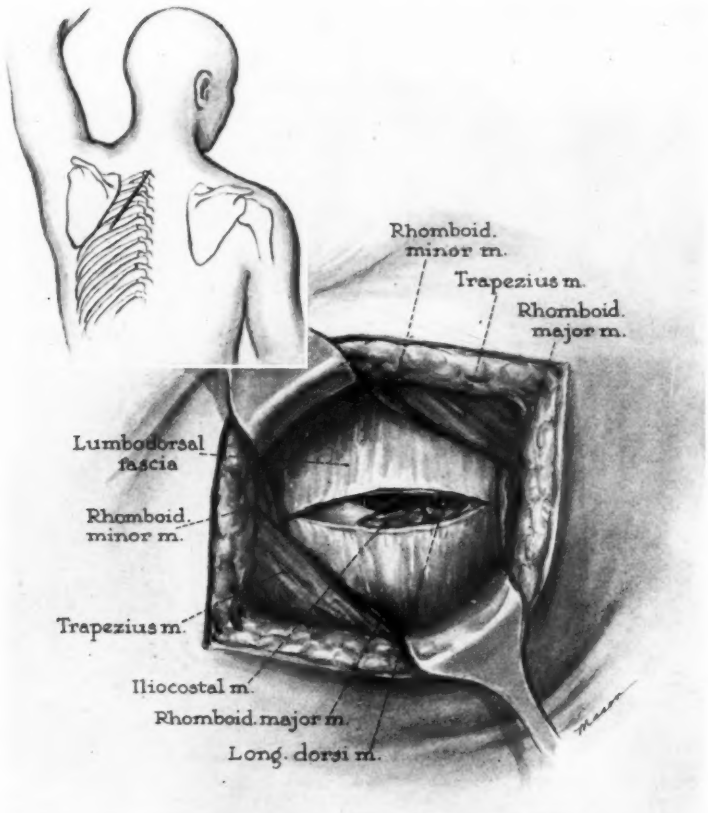

Fig. 4a. Dorsal sympathectomy. Patient is in the prone position with an inflated horseshoe pillow under the chest. His face rests on a cerebellar rest. The incision starts slightly below and lateral to the spinous process of the 7th cervical (prominens) vertebra. The incision runs parallel to the medial border of the abducted scapula. The first layer of muscle, namely the trapezius, is split in the direction of its fibers. The rhomboid muscles, major and minor, are retracted and the strong lumbodorsal fascia is split transversely. The long muscles of the back are separated to expose the 3d rib.

intravenous sulfur compounds for the correction of the oxygen unsaturation which they found to accompany exacerbations of the disease. In a recent study I found that these sulfur compounds, notably sodium tetrathionate, restore the heparin response of such patients to normal (3). While in previous years it has been our practice to "cool off" the active process by a series of small doses of typhoid vaccine with complete abstinence from tobacco, now one can safely proceed with the operation in about 1 week (Fig. 2).

The heparin tolerance is thus a useful gauge of the activity of the disease; in cases of recurrence, brought about by trauma or renewed smoking, it flattens again. It also permits a close watch for postoperative thrombosis for which preventive measures are available.

Since the disease is far more widespread than would be obvious from a clinical examination, eyegrounds are examined, an electrocardiogram is taken, and renal concentration is determined. Isolated phlebitis or periphlebitis in retinal veins has thus been

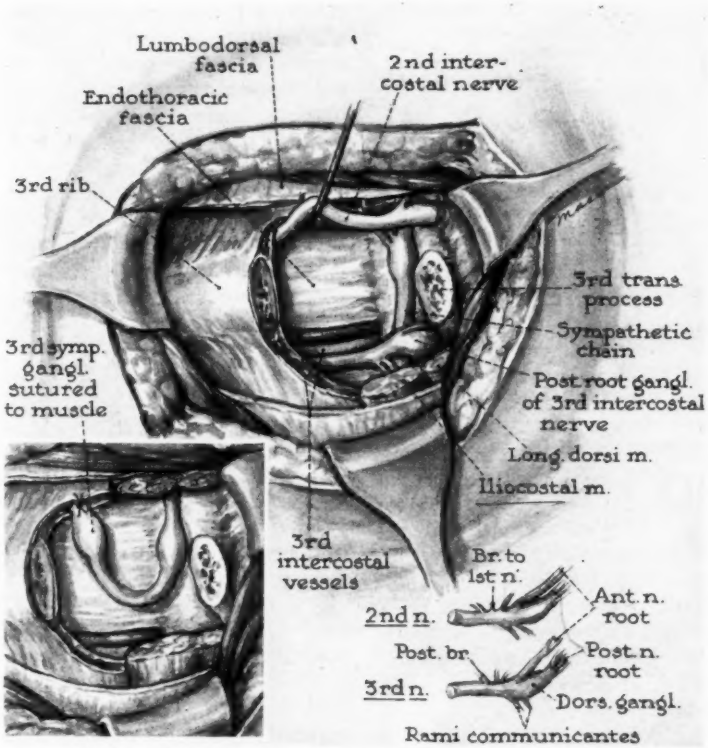

Fig. 4b. The 3d rib has been resected paravertebrally for a length of 6 centimeters. The transverse process has been removed with a double action bone forceps. The pleura with the endothoracic fascia has been peeled off the vertebral bodies. The 2d and 3d intercostal nerves are pulled out gently from the intervertebral foramina and sectioned proximal to the posterior root ganglion intradurally. A small segment of the nerve is excised. (See insert in lower right quadrant.) The sympathetic chain is cut below the 3d dorsal ganglion and sutured to muscle or to the distal stump of the second intercostal nerve. A Cushing clip is placed on the lower end of the sympathetic chain. The wound is closed in layers with cotton. Method of Smithwick.

recognized; myocardial damage is not infrequent. A small group of our patients had hypertension with typical arteriolar lesions of Buerger's disease in the periphery and another group had cerebral symptoms (Table I).

The finding of such widespread involvement does not necessarily contraindicate sympathectomy for one especially crippled part of the body; but it aggravates prognosis and may require prolonged preoperative management.

CONTRAINDICATIONS TO SYMPATHECTOMY

Early cases of thromboangiitis with migrating phlebitis, with closure of a single digital artery or with an acute phlegmon of a finger or toe, simulating gout, are not suitable for sympathectomy; their sedimentation rate is slow and the hematocrit is high. Moreover, patients over 50 years of age, whose disease is slowly burning out and who have a certain degree of arteriosclerosis, are generally not suitable for sympathectomy; the vasomotor element is not striking. The operation is indicated when the disease seems quiescent, when the hemoconcentration is corrected, when the collateral blood supply is satisfactory, and when the visceral involvement is not too widespread.

TABLE I.—VISCERAL LESIONS IN THROMBOANGIITIS OBLITERANS

	No. patients	Percentage of total
Number of patients studied	50	
Retinal lesions (vasoconstriction / periphlebitis)	13	26
Cerebral vascular lesions	5	10
Electrocardiogram, abnormal pattern	28	56
Duodenal ulcer	5	10
Impaired renal function	8	16
Pulmonary fibrosis	2	4
Occlusion of spermatic artery	1	2

It is not implied that these lesions are necessarily due to a thromboangiitis.

THE SURGICAL PROCEDURES

Lumbar sympathectomies have been done alternately under intratracheal ether or high spinal anesthesia. Since the approach used is an extraperitoneal anterolateral muscle-splitting incision (5), complete muscular relaxation is very important. Bleeding from lumbar vessels is controlled by Cushing clips. A retroperitoneal lymphangitis and lymphadenitis may greatly interfere with dissection. These may be encountered even when there is no infected ulceration in the periphery. Biopsy or culture of these lymph glands has not yielded any specific information. The ganglionated trunk should be removed from the sacral promontory to the diaphragm, but at least between the top of the 2d to the bottom of the 3d lumbar vertebra. The number and size of the ganglia vary a great deal and duplicate chains are sometimes encountered (Fig. 3). Patients usually get up the 5th and go home the 10th postoperative day.

The dorsal sympathectomy for the arm is done under intratracheal ether anesthesia. The 3d rib is resected paravertebrally, the 2d and 3d intercostal nerves with the corresponding anterior and posterior roots are removed intradurally, and the chain is sectioned below the 3d ganglion. The distal end is clipped with a metal clip, the proximal end is implanted into muscle. We do not wrap the chain into a silk cylinder, but otherwise follow the method described by Smithwick (Fig. 4). The patient is allowed to get up on the 3d day and may be home on the 8th day.

In a number of cases amputations have been performed during the time of sympathectomy, especially on the lower extremities. As stated before, if the paravertebral block results in a failure to warm a certain part or especially if a paradox drop of temperature is observed, the corresponding digits are removed. To obtain primary union it is necessary to obtain positive histamine flares at the level of amputation, to use absolutely no tension on the sutures, and to suture nothing but skin. When all five toes need to be amputated, a Gigli saw is used. With the protection of a sympathectomy, a Syme amputation has been recently used in patients who without the sympathectomy would have had to have a lower leg amputation. The results of this combined operation of sympathectomy and amputation will be discussed in more detail.

Lately the skin incision has been placed so as to run parallel with the fibers of the external oblique muscle. A detailed description of this excellent technique, which avoids undercutting of the skin and subcutaneous tissue and provides excellent exposure, is given by Pearl in a recent contribution.[1]

POSTOPERATIVE MANAGEMENT

Patients following lumbar sympathectomy receive prostigmine every 4 hours in 10 doses. This not only controls intestinal and bladder atony but has a beneficial effect on the clotting tendency of the postoperative status (4). In addition, sodium tetrathionate is used, 3 ampuls the first day in the intravenous fluids, and 1 ampul daily until the patient is mobilized.[2] This, too, is useful in counteracting the heparin resistance which such patients exhibit after operations. There has been no thrombosis or embolism in this small series, but of course this is statistically meaningless. However, even an established migrating phlebitis of Buerger's disease responds very quickly to this treatment.

RESULTS OF SURGICAL PROCEDURES

To evaluate the results, a grouping of these patients into (1) those who have had only sympathectomies, (2) those who had sympathectomies combined with minor amputations, and (3) those who had sympathectomies combined or followed by major amputations,

[1] Pearl, F. L. Surg. Gyn. Obst., 1937, 65: 107.

[2] Sulfa drugs should never be used in combination with sodium tetrathionate.

seemed practical. Table II shows the results obtained. Obviously the first group is the least advanced one; the two part time workers had not secured inside jobs and probably could be placed to do full time work elsewhere; the two invalids were of the lowest economic and intellectual level and their re-education seemed impossible. In the second group, the 3 patients who could work only part time were middle-aged laborers, streetcar conductors, or railyard workers. The invalids had cerebral involvement. In the last group, 2 patients could not be fitted with artificial legs and 1 patient had a pension which allowed him to live without having to work.

TABLE II.—RESULTS OF SURGICAL TREATMENT IN BUERGER'S DISEASE

Group	No. cases	No. operations	Full time work	Part time work	Invalid
1	24	56	20	2	2
2	21	63	15	3	3
3	5	17	2	2	1
Total	50	136	37	7	6

Group 1 had only sympathectomies.
Group 2 had sympathectomies combined with minor amputations.
Group 3 had sympathectomies combined with major amputations.

POSTOPERATIVE COURSE

Horton has written a very interesting article in 1938 on the outlook in thromboangiitis obliterans and thought that the most important factors which determine whether a person who has thromboangiitis obliterans will walk on two feet thoughout life are early diagnosis and education of the patient concerning the nature of his disease and the care of the extremities. One thing that our group has learned is the importance of re-educating and reallocating these patients to jobs which will expose them less to the hazards of trauma, exposure to cold, or excessive use of the feet. All patients suffering from Buerger's disease should be regarded as handicapped. If they are office workers, their jobs should be sedentary; if they are laborers, their jobs ought to be inside. A streetcar conductor with thromboangiitis obliterans is just as unfit for his job as if he were a parachute trooper or an aviator. Widespread use of agencies to reallocate such people will result in continued improvement.

Table III shows the occupations of this group of patients. Most surgeons are emphatic about abstinence from tobacco and about the care of the feet. How many of us are emphatic about a change of occupation? It is not enough to suggest it, but one should also aid the patient by agencies now available for the purpose. This is surely as important as the printed directions regarding the care of the feet, but more difficut to accomplish.

Our patients are instructed to appear every 3 months for a year and then once a year for a re-examination. They are given printed instructions regarding the dangers to avoid. They are advised to take two series of 12 daily injections of sodium tetrathionate during the first year. They are taught the use of intermittent venous hyperemia on the sympathectomized extremity, which method is notoriously ineffective in this disease unless the vasomotor control is interrupted. While these measures are important, they are of not very much use without sympathectomy. Fourteen patients with unilateral sympathetic denervation are vociferous witnesses of the progress that the extremity operated upon makes compared with the other limbs. These patients, to my mind, are the most convincing proof of the value of sympathectomy in the presence of Buerger's disease.

SUMMARY

Sympathectomy deprives the extremity of its vasoconstrictor tone. It does not influence the course of Buerger's disease. However, when this disease is in an inactive phase and when adequate preoperative tests reveal the presence of sufficient collateral vascular supply, sympathectomy will aid an extremity considerably whose vessels have been crippled by recurrent attacks of segmental thrombosis. In this series of 50 patients 136 sympathectomies have been done; about one-half of these patients have also had minor amputations combined with sympathectomy. Of the 50 patients, 37 have been rehabilitated to full time work, 7 are doing part time work, and only 6 are invalids. In addition to foot hygiene and complete abstinence from tobacco, a change of occupation is important for those whose feet are continuously subjected to an exposure to cold or trauma.

TABLE III.—OCCUPATION OF PATIENTS

Office work	15
Physician	5
Lawyer	2
Housewife	3
Laborer	8
Outside work (motorman, etc.)	5
Travelling man	7
Farmer	5
Total	50

ILLUSTRATIVE CASE HISTORIES

CASE 1. John S., 32 year old streetcar conductor, complained of claudication after one block. He had had pain in lower leg and foot since hitting the dorsum of his left foot with a tennis racket 10 years ago. Erythematous patches occurred during the cold months. Ring finger of right hand became blanched at times. Gastric ulcer was found in January, 1943. He had always been a heavy smoker. On entrance to hospital left foot was colder than right; erythematous induration was present on left tibial margin. Heparin curve showed increased tendency to clotting. Sympathetic block to 2d, 3d, and 4th lumbar ganglia gave a moderate rise in temperature. The big toe remained cold. Claudication 175 steps before block; walked 30 minutes after block without pain. Electrocardiogram revealed a right axis deviation.

Operation on June 17, 1943 consisted of a left lumbar sympathectomy. Big toe became warm under ether anesthesia and was not amputated. Large lymph glands were encountered retroperitoneally. On January 12, 7 months after operation, the patient reported that he worked 8 hours a day as a bus driver. He could play 18 holes of golf. The big toe was sometimes numb. He stopped smoking and took two courses of sodium tetrathionate.

This patient, a 32 year old male with a pronounced angiospastic claudication, derived great benefit from a lumbar sympathectomy. His big toe seemed to have most of the organic damage, but the disease seems to have been arrested at this stage.

CASE 2. J. J. M., a 39 year old pharmacist, entered St. Luke's Hospital on November 8, 1940, complaining of persistent severe pain at rest, inability to walk, and inability to sleep, with symptoms gradually increasing for the last 2 years. He was frostbitten at the age of 8 and had always seemed sensitive to cold. He had smoked 1 to 2 packages of cigarettes daily for 20 years. His right 4th toe had ulcerated 4 weeks ago. He had been previously treated for Raynaud's disease. On entrance, the right lower extremity was cold, the toes cyanotic, the 4th toe ulcerated. There was extensive dental infection. In the electrocardiogram P_3 was inverted, T_3 low. Fifteen minutes after the intravenous injection of phenolsulfonphthalein 20 per cent was excreted in the urine, showing a delay in excretion. The eyegrounds showed arteriolar constriction and tortuosity; a stellate block had a definite dilator effect indicating vasospasticity. Operation on November 16, 1940, consisted of a right lumbar sympathectomy. Considerable lymphadenopathy was noted. A follow-up in December, 1943, revealed that he could walk from 3 to 4 blocks, that he was working 8 hours a day in a defense plant. The ulcer had completely healed.

This 39 year old pharmacist has been followed for 3½ years after sympathectomy. The disease seems to be arrested. He is able to perform full time work.

CASE 3. E. F. S., 41 years old, unemployed, entered St. Luke's Hospital on April 19, 1939, complaining of pain, numbness, cramping on walking for the past 6 years. He had not worked for 3 years. On entrance both lower extremities were pale, cold, and pulseless below the knees. There was a massive necrosis of the entire left big toe which was present for over a year. He had been previously treated for diabetes and for syphilis. Maggots were applied to the toe. The electrocardiogram revealed a slightly elevated *S-T* segment in lead II. Renal concentration was within normal limits. The veins were slightly darker than usual in the retina.

On April 20, 1939, a right lumbar sympathectomy, on May 5, 1939, a left lumbar sympathectomy, on May 8, 1939, amputation of the left big toe were performed. A follow-up inquiry in December, 1943, revealed that he could walk 3 miles without pain, had an occasional twinge in the left toes which passed immediately, and that he was at full time work in a defense plant.

This 41 year old male, unable to work for 3 years, had been fully rehabilitated by bilateral lumbar sympathectomy and amputation of one toe. Period of follow-up was 4½ years.

CASE 4. Nick F., 53 year old foreman, entered St. Luke's Hospital complaining of pain and increasing inability to walk very far for the past 3 years. He first noticed sensitivity to cold and cramping on walking, first in right and then in left leg 20 years ago. In December, 1941, a paronychia developed in left big toe; when the toenail was removed the toe became gangrenous. He smoked a package of cigarettes a day for many years.

On entrance he had claudication after 50 feet. There were diminished femoral, absent popliteal and pedal pulses on the left. The big toe was gangrenous. The right foot was equally pulseless but warm and painless. Blood pressure was 150/90. Ratio of veins to arteries in the retina was 2:1. The electrocardiogram showed a W-shaped *QRS* complex in lead III. X-ray examination of the popliteal fossa showed some calcification.

Operation was done on January 9, 1942. A left lumbar sympathectomy was done with removal of the chain between 2d and 4th lumbar segments. The toe was removed 5 days later since his blood pressure fell to 60 millimeters of mercury, probably because of his posture on the table. A plantar abscess had to be drained before the incision on the foot completely healed. Re-examination 9 months and 12 months after sympathectomy revealed an ability to walk 4 to 5 blocks a day; both feet were painless. He works on his feet 10 to 12 hours a day. Oscillometer revealed a ½ centimeter oscillation at 100 millimeters of mercury at both ankles. These were absent prior to operation.

This 53 year old male, with signs of beginning arteriosclerosis superimposed on an old Buerger's disease, increased his walking ability from 50 feet to 4 blocks and could do a full day's work after a combination of sympathectomy and minor amputation. The differential diagnosis between presenile atheromatosis and Buerger's disease is not possible in this case. Both may have been present.

CASE 5. E. M. R., a 35 year old automobile salesman, complained of intermittent claudication for 2 years and a left infected ingrown toenail for 2 years. He had been treated by a chiropodist until 1941, then by a physician who incised his foot. He visited a university clinic, where he received instructions for the care of his feet. On entrance to St. Luke's Hospital there was bilateral absence of pedal pulses but both popliteals were present. His heparin curve was 3, 5, 3, 3 minutes, coagulation times being determined every 10 minutes. After a course of sodium tetrathionate, the coagulation times were 4, 7½, 6, 4, 4. Sympathetic block to 2d lumbar segment resulted in marked vasodilatation and dryness of the right foot and toes. The left toes remained cold. Electrocardiogram revealed a low *QRS* in leads I, II and III.

On January 23, 1943, left lumbar sympathectomy was performed. There was a large chain of lymph glands. On February 8, 1943, a right lumbar sympathectomy was performed and again a great deal of lymphadenitis was encountered. He went to work in a railroad yard, exposing his feet to much trauma and cold. He never stopped smoking, even while in the hospital.

A follow-up in November, 1943, 6 months after a bilateral sympathectomy, revealed that his left leg had been amputated at Cook County Hospital.

This 35 year old male had a severe terminal type of Buerger's disease. Bilateral lumbar sympathectomy was done, but this failed to prevent the loss of one leg. Possible causes of this failure: (1) inability to stop smoking; (2) unsuitable, outside manual labor in a man used to indoor desk work; (3) failure to remove toes at the time of sympathectomy which failed to warm on sympathetic block.

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HYPOPROTEINEMIA IN THORACIC SURGERY

A Clinical Study

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RATHER extensive studies have been made on the effect of hypoproteinemia in surgical diseases. It has been found that certain conditions, particularly long standing intestinal obstruction, are prone to produce a marked lowering of the plasma proteins. The effect of this hypoproteinemia on wound healing and disruption, postoperative infections, and rate of recovery has been the subject of many observations (2, 3, 5, 6). Most of the work to date has concerned major abdominal surgery. The surgical treatment of diseases of the chest may also be complicated by hypoproteinemia, largely due to the chronicity of many lung diseases and the relatively severe blood loss associated with major thoracic surgery.

Over a 12 month period the effect of the more common chest operations on plasma proteins has been investigated. The studies were conducted in the following manner. Preoperative plasma protein and hematocrit determinations were made on all patients. During the operations and in the postoperative period rather large whole blood and plasma transfusions were given to replace blood loss. No operations were begun without a cannula in place and blood started or available. Infusion was usually discontinued in explorations for inoperable lesions; in the case of resections, blood was added to roughly compensate the loss. At 2 day intervals following operations the plasma proteins and hematocrit determinations were repeated. The study was continued for 10 days, or until the readings returned to the preoperative level. All protein determinations were made in the hospital laboratory by the micro Kjeldahl method (4). Included in the series are 32 major operations on 29 patients, classified as follows:

From the Department of Surgery of the University of Chicago. This work supported in part by a grant from the Douglas Smith Foundation for Medical Research of the University of Chicago.

1. Lobectomy		14
a. Left lower	6	
b. Left lower and lingula	2	
c. Right lower	1	
d. Right middle	2	
e. Right middle and lower	3	
2. Pneumonectomy		5
3. Exploratory thoracotomy		7
4. Miscellaneous		6
a. First stage lobectomy	1	
b. Esophageal resection	2	
c. Partial pericardectomy	1	
d. Extensive thoracoplasty	2	

One patient succumbed 15 days after operation due to anuria and uremia induced by sulfathiazole. The remainder recovered from the operation satisfactorily.

RESULTS

Pertinent data on the individual patients are presented in Table I. Despite the fact that chronic suppurative lesions and carcinoma were the most common diseases, preoperative hypoproteinemia was rare. Only 2 patients had basal readings below 6.00 grams per cent. Following operation a rather marked fall in the plasma proteins occurred in every patient but one. In the case of lobectomy this fall averaged 1.11 grams per cent and varied from 0.44 to 2.91 grams per cent. The greatest fall occurred in 4.4 days, and the preoperative level was regained in 9.0 days. The drop in plasma proteins was accompanied by a hematocrit fall of 5.8. The lowest hematocrit reading occurred in 4.3 days and had returned to the preoperative level in 9.5 days. The fall in hematocrit was not constant; 5 cases of lobectomy maintained the preoperative hematocrit level, the greatest drop being 15 points. At the time of lobectomy the average transfusion was 942.8 cubic centimeters of whole blood; in the postoperative period an additional 782.1 cubic centimeters were given.

The average plasma protein fall in 5 cases of pneumonectomy was 0.95 gram per cent, the range being from 0 to 1.54. The greatest drop

occurred in 3.7 days and had returned to the preoperative level by 11.5 days. The lowering of hematocrit ranged from 0 to 16 with an average fall of 7. The greatest drop occurred in 2.7 days and returned by 6.2 days. One case of pneumonectomy is not included in the hematocrit averages since he had polycythemia before operation and was given only plasma. His hematocrit fall of 30 can be explained on the basis of the large plasma transfusion (2400 c.c.). At the time of operation the average pneumonectomy patient received 2060 cubic centimeters of blood, with an additional 630 cubic centimeters early in the preoperative period.

The 7 cases of exploratory thoracotomy did not receive massive blood transfusions. The average at the time of operation was 642.8 cubic centimeters, and no transfusions were given after operation. The postoperative fall in plasma proteins averaged 0.77 gram per cent and ranged from 0.39 to 1.34 grams per cent. The fall was greatest in 3.3 days, and in half the cases had not returned to the preoperative level by the time of discharge. The hematocrit fall averaged 4.8 in 6 days and in over half the cases did not return. The failure of the blood to return to the preoperative level was attributed to lack of enthusiastic replacement therapy and progress of the disease.

The data in the group of miscellaneous operations show the same trend as in lobectomy and pneumonectomy, but they have not been averaged because of the diversity of the diseases and operations.

ANALYSIS OF STUDY

Various factors are responsible for the appreciable fall that occurs in plasma proteins after operation. A high percentage of these patients present themselves with advanced malignant lesions or chronic infection. Their diet has been inadequate because they have had no desire to eat. While this has not resulted in a preoperative hypoproteinemia in these cases it may tear down the protein reserve. There is good evidence to support the idea that the plasma protein reserve is deficient in these patients with chronic illnesses. The group of exploratory thoracotomies may be used as a control since replacement therapy was not enthusiastic. The majority of exploratory operations received only one blood transfusion. The postoperative protein fall (0.77 gm. %) was not as marked as in the other groups (probably since the operation, and therefore the blood loss, was less extensive) but 3 of the 7 patients had not returned to the preoperative level by the time of discharge. In fact, except for 1 case with a slight fall (0.39 gm.%) in none of the exploratory operations did the plasma proteins return as soon as in the more vigorously treated patients. This seems to indicate that the ability of the body to regenerate proteins in these individuals was markedly impaired.

Operations on the chest are time consuming and are associated with the loss of large amounts of blood. Thick, vascular muscles must be cut across in making the incisions; our average time for a lobectomy is 1½ to 2 hours; total pneumonectomy requires 3 hours or longer. White and Buxton have measured the blood loss in the more common thoracic operations; they found an average blood loss of 1607.5 cubic centimeters in 10 lobectomies and an average blood loss of 1458 cubic centimeters in 6 pneumonectomies (7). One of us (PWS) has made similar studies in our cases with comparable results. We are convinced that the blood loss at operation will be grossly underestimated unless some reasonably accurate measurement is made. To this must be added the appreciable amount of blood removed along with the resected lung; even if the lung is perfused to wash out the blood for measurement, much is still retained in the specimen. There is considerable seepage into the wound and postoperative effusion into the pleural cavity. The latter will be discussed more thoroughly.

This rather marked blood loss must place a severe strain on the protein forming mechanism, unless massive blood transfusions are employed. The loss of 1 to 2 liters of blood cannot be adequately replaced by any means except generous whole blood transfusions. It was our aim to replace every cubic centimeter of blood loss. For this reason blood substitutes were not employed. They may supply protein adequately but they cannot replace lost red cells. The use of plasma is subject to the same objection. Our replacement therapy was not

TABLE I

Initial	Diagnosis	Operation	Infection	Replacement in c.c.	Plasma proteins					Hematocrit			
					Preop.	Fall	P.O.	Day fall	Day return	Fall	Day fall	Day return	Pl. fl. loss
Lobectomy													
1. M.B.	Bronchiectasis	Left lower lobectomy	+	1000 at operation	7.92	1.60	6.32	7	—	0	—	—	700
2. M.S.	Bronchiectasis	Left lower lobectomy	—	500 at operation 500 after	6.94	1.82	5.12	3	9	13	5	9	200
3. J.M.	Bronchiectasis bilateral	Left lower lobectomy	—	1500 at operation	7.02	0.46	6.56	4	9	0	—	—	600
4. J.C.	Congenital cystic disease	Left lower lobectomy	+	500 at operation 1250 after	6.53	0.96	5.57	6	10	8	6	Not back	?
5. A.R.	Diffuse suppurative pneumonia, pneumonitis	Left lower lobectomy	—	600 at operation 500 after	6.09	0.93	5.16	3	14	5	2	Not back	1150
6. H.F.	Bronchiectasis	Left lower lobectomy	+	500 at operation 1900 after	6.96	1.48	5.48	5	12	13	3	10	1265
7. M.S.	Tuberculous bronchiectasis	Right lower lobectomy	—	700 at operation 800 after	6.36	0.55	5.81	3	6	5	6	10	875
8. L.F.	Congenital cystic disease	Left lower lobectomy, partial left upper	—	500 blood at operation and 300 plasma 700 blood after	7.53	2.91	4.62	1	10	15	2	8	?
9. B.K.	Bilateral bronchiectasis	Left lower lobectomy, left lingulectomy	—	1000 at operation	6.68	0.76	5.92	1	2	0	—	—	930
10. A.S.	Bilateral bronchiectasis	Right middle and lower lobectomy	+	500 at operation 2500 after	7.22	0.74	6.48	7	Did not return	0	—	—	990
11. D.G.	Bilateral bronchiectasis	Right middle and lower lobectomy	+	650 before operation 1000 at operation 500 after	7.55	1.60	5.95	4	17	0	—	—	500
12. R.T.	Bronchial adenoma	Right middle and lower lobectomy	—	2700 at operation 2100 after	6.35	0.44	5.91	6	9	7	1	9	430
13. M.F.	Congenital cystic disease	Right middle lobectomy	—	1000 at operation	7.12	0.70	6.42	1	2	6	6	11	30
14. E.S.	Diffuse suppurative pneumonitis	Right middle lobectomy	—	1000 at operation	6.84	0.69	6.15	11	Did not return	10	8	Not back	420
Average 14			5+	942.8 at operation 782.1 after	6.93	1.11	5.82	4.4	9.0	5.8	4.3	9.5	673.3
Pneumonectomy													
1. M.H.	Carcinoma lung	Left total pneumonectomy	+	2500 at operation 900 after	7.42	1.54	5.88	3	13	16	4	13	?
2. L.R.	Carcinoma lung	Right total pneumonectomy	—	1300 at operation 900 after	6.85	1.12	5.73	4	12	11.0	3	6	?
3. J.K.	Carcinoma lung	Right total pneumonectomy	—	2600 at operation 550 after	6.44	1.40	5.04	4	13	0	0	0	?
4. G.S.	Carcinoma lung	Right total pneumonectomy	—	1500 at operation	6.25	0.69	5.56	4	8	1	4	6	?
5. R.R.	Hemangioma	Left total pneumonectomy	—	2400 at operation 800 after	5.32	0	5.58	0	0	30	—	—	?
Average 5			1 + 20%	2060 at operation 630 after	6.45	0.95	5.56	3.7	11.5	7	2.7	6.2	?

adequate as evidenced by the postoperative fall in hematocrit. The hematocrit determination was employed because it was found to be more sensitive and accurate than the usual hemoglobin or red cell count. Eight patients in the entire group did not have a postopera-

TABLE I—Continued

Initial	Diagnosis	Operation	Infection	Replacement in c.c.	Plasma proteins					Hematocrit			
					Pre-op.	Fall	P.O.	Day fall	Day return	Fall	Day fall	Day return	Pl. fl. loss
Exploratory Thoracotomy													
1. C.S.	Carcinoma lung	Exploratory thoracotomy	−	1000 before operation 500 at operation	7.33	0.51	6.90	6	9	0	—	—	0
2. A.K.	Tuberculosis?	Exploratory thoracotomy	−	500 at operation	5.92	0.80	5.12	2	14	15	5	Not back	475
3. E.B.	Carcinoma esophagus	Exploratory thoracotomy	−	500 at operation	6.18	1.00	5.18	10	13	3.5	13	Not back	350
4. F.R.	Carcinoma lung	Exploratory thoracotomy	−	500 at operation	5.70	0.39	5.31	1	3	3	5	Not back	0
5. M.N.	Carcinoma lung	Exploratory thoracotomy	−	1000 at operation	7.89	1.34	6.55	7	Not back	3	3	7	0
6. E.S.	Mediastinal cyst	Excision of	−	500 at operation	6.71	1.01	5.70	1	Not back	6	4	6	150
7. C.H.	Carcinoma esophagus	Thoracolaparotomy	−	1000 at operation	6.52	0.40	6.12	6	Not back	4	6	Not back	200
Average 7			0	642.8 at operation 0 after	6.60	0.77	5.84	3.3	9.7+	4.8	6	+	167.8
Miscellaneous													
1. R.T.	Bronchial adenoma	First stage lobectomy	−	3200 at operation 1500 after	6.88	1.22	5.66	6	13	5	1	6	0
2. L.B.	Carcinoma esophagus	Esophagectomy anastomosis	+	2000 at operation 1500 after	6.44	0.98	5.46	6	15	6	4	5	400
3. J.V.	Carcinoma esophagus	Torek	−	1250 at operation	6.28	0.33	5.95	2	6	10	3	Not back	100
4. F.VW	Constrictive pericarditis	Partial pericardectomy	−	500 at operation	6.94	1.82	5.12	12	25	8	8	Not back	3700
5. G.S.	Post. pneumonectomy empyema	Thoracoplasty	+	1500 at operation 500 after	6.42	1.02	5.40	2	9	6	4	7	Open
6. L.R.	Post. pneumonectomy empyema	Thoracoplasty	+	1500 at operation 500 after	6.94	0.78	6.16	1	6	0	—	—	Open

tive hematocrit drop. These patients would be expected to show a less severe fall in plasma proteins. Unfortunately, 4 of the 8 patients developed postoperative infections which complicated the picture, and on the average these patients had as marked a protein fall as the entire series. It is probably true, however, that the fall in protein would be minimal if the hematocrit could be maintained at a constant level.

Following operation there is a short period of negative nitrogen balance due to restriction of diet. Usually this is not as prolonged as in major abdominal surgery. After pneumonectomy the remaining pleural space is obliterated largely by serum from the blood stream. Following lobectomy a considerable amount of bloody serum is aspirated from the pleural cavity with a needle or continuous suction. We have measured this loss in 12 consecutive lobectomies and find that it averages 673.3 cubic centimeters. Further loss of serum occurs if the wound becomes infected. The postoperative loss of serum and blood presents the same problem as operative hemorrhage, with the exception that the loss is over a period of days instead of hours, and the fluid contains fewer red cells. This may offer an indication for the use of blood substitutes and plasma, which would also tend to neutralize the effect of the negative nitrogen balance.

Some consideration should be given to the optimal time for replacement therapy. In this group of patients preoperative transfusions were usually not given unless an anemia of less than 4.0 million red blood cells was present.

If operative blood loss is unusually severe, or if the infusion apparatus functions poorly, the replacement may fall far short of the loss. It seems advisable to anticipate such incidents and employ preoperative transfusions to a greater extent than is usually practiced, particularly if the plasma proteins are low before operation. This would provide the patients with a margin of safety should a minor accident occur in the operating room with the infusion set-up or the supply of blood. Should a marked fall in the plasma protein level occur after operation, further transfusions should be given promptly as will be shown.

If a postoperative infection occurs there is further loss of protein and electrolytes. There can be little doubt that a fall in plasma protein occurs with severe infection. Infection occurred following 9 of the 32 operations in this series. The protein fall in the infected patients averaged 1.19 grams per cent, as opposed to a fall of 0.92 gram per cent for the noninfected group, and 0.99 gram per cent fall for the entire series. In view of the susceptibility of debilitated patients to infection, the hypoproteinemia may be the cause rather than the result of some postoperative infections.

Some indication of the individual effect of these various factors was determined in experimental work recently reported from this laboratory (1). With dogs as the experimental animal, it was found that ether anesthesia alone caused an average plasma protein fall of about 0.50 gram per cent. Exploratory thoracotomy resulted in a fall of 0.85 gram per cent. Left lower lobectomy was accompanied by a protein drop of 1.5 grams per cent. Removal of the left lung caused the protein level to fall about 1.3 grams per cent. If infection occurred the drop was more marked and stayed at a low level longer than in noninfected animals. The use of whole blood intravenously, and serum intravenously or intrapleurally, partially prevented the plasma protein fall. The most striking feature of the study was the marked lowering of plasma proteins by postoperative infection.

A comparison of patients demonstrating the most marked protein fall against those who had a slight drop serves to emphasize the cause for postoperative hypoproteinemia. Using the lobectomy group as an example, we found that Cases 8, 2, and 1 had the greatest drop (2.91 gm.%, 1.82 gm.%, and 1.60 gm.%, respectively). Cases 12, 3 and 7 had the least fall (0.44 gm.%, 0.46 gm.%, and 0.55 gm.%, respectively). In the group of 3 patients demonstrating the severe fall, operative blood loss was excessive in only one instance (Case 8). Postoperative fluid loss was slightly less than in the average case. One of the 3 patients became infected. However, replacement therapy was not adequate. The average transfusion at the time of operation was 766 cubic centimeters with an additional 466 cubic centimeters during the postoperative period. (In Case 8 for simplicity a 300 cubic centimeter plasma transfusion [at the time of operation] is included with the figures for whole blood.) The hematocrit determinations show the same trend. Case 1 had no fall, but Cases 2 and 8 had hematocrit drops of 13 and 15, respectively, an indication that replacement was entirely inadequate.

In 2 of the patients with a slight protein drop, blood loss at the time of operation was extreme (Cases 3 and 12). The postoperative loss of fluid into the pleural space was no greater than the average. No postoperative infections occurred. Considerably more blood was given than in the first group. Case 3 received 1500 cubic centimeters of blood at operation; Case 7 was given 700 cubic centimeters of blood at operation, and 800 cubic centimeters after operation; Case 12 received 2700 cubic centimeters of whole blood during the operation and 2100 cubic centimeters during the first week following operation. The hematocrit readings reflect the extensive replacement; the fall in Cases 3, 7, and 10 was 0, 5, and 7, respectively. This comparison demonstrates the extreme importance of massive blood transfusions; if replacement closely approximates the loss, much less deviation from the preoperative values occurs.

The fall of plasma proteins following operation is largely of academic interest unless the value reaches a point sufficiently low to be of some danger to the patient. Obviously if the preoperative value was well over 7.00 grams per cent the loss of 1.00 gram per cent still leaves the plasma proteins in the normal range. It is necessary to consider whether an appre-

ciable number of patients drop into a dangerously low level, which is usually considered to be in the neighborhood of 5.50 grams per cent. Of the 32 operations reported here, 11 caused the plasma proteins to fall below 5.50 grams per cent. The lowest reading was 4.62 grams per cent (Case 8 in the lobectomy group). These 11 patients did not have a higher incidence of infection than the rest of the group, but they were, for the most part, cases in which smaller amounts of blood were given. The fact that one-third of the patients fell below 5.50 grams per cent following operation is a clear indication of the practical importance of this problem.

The prompt recovery that occurred in all but 1 patient in this group is partially due, we believe, to the liberal use of whole blood. If the transfusion given at operation did not prevent a fall in plasma proteins, blood was given liberally after operation until the protein level was well above 5.50 grams per cent. The frequent use of the hematocrit determination is a rapid, simple method by which the amount of infused blood can be controlled until a protein reading is available.

SUMMARY

1. A plasma protein fall of approximately 1.00 gram per cent occurred following major thoracic operations. This drop was constant; it occurred in 31 of 32 operations reported in this series.

2. The fall usually occurred from 3 to 5 days following operation, and was accompanied by a similar decrease in hematocrit, hemoglobin and, to a lesser degree, red blood cells.

3. The principal causes of the drop in plasma protein were: (a) diminished protein reserve, (b) operative blood loss, (c) loss of blood and plasma into the wound and pleural space after operation, (d) infection, (e) inadequate replacement.

4. Massive transfusion of whole blood was the most satisfactory single therapeutic agent when the plasma proteins were lowered due to hemorrhage.

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MATERNAL OBSTETRICAL PARALYSIS

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THE study of those parts of a field of investigation in which different aspects of knowledge meet on common ground might be expected to be a particularly valuable one. In such zones of overlap the scrutiny of problems from different viewpoints may lead to their rapid solution. It is therefore surprising to find that these frontier territories have frequently been left relatively unexplored. Certain neurological complications of pregnancy and labor illustrate this point. Although the complications fall within the practice of the obstetrician, being neurological, they are usually of but little interest to him. On the other hand the neurologist probably sees but a small proportion of these cases and has, as a result, tended to regard the conditions as rare complications of pregnancy and labor. A study of the well known textbooks of obstetrics and medicine reveals that, for the most part, the neurological disturbances to be considered either have been entirely overlooked or receive but the briefest mention. This neglect cannot be attributed to the rarity of their occurrence and indeed it appears likely that weakness of certain muscles of a lower limb after labor is a great deal more common than is generally realized. As a result of certain personal observations it is believed that further light can be shed upon this group of cases, and the purpose of this paper is, therefore, to attempt to lead to a better understanding of certain results of the physical trauma of childbearing.

THE MODERN TEACHING

Under the title of neuritis of pregnancy and the puerperium, there are grouped together several conditions of differing etiology. In one group of cases the evidence of neurological disturbance is irregularly distributed throughout the body and may be severe and widespread. It has been suggested that toxemia, vitamin deficiency, and puerperal sepsis may be important etiological factors in these cases. This group is outside the scope of the present communication, however, and will not be further considered. In a second and larger group the neurological disturbance affects one or both lower limbs. It takes the form of a so-called peripheral neuritis and may arise in pregnancy or follow labor. This paper is concerned solely with the second group of cases, that is neuritis involving the lower extremities. The development of the modern conception of the etiology of this condition will now be briefly considered. Arguments against this modern view will then be put forward. Finally evidence for an alternative explanation will be given.

In 1854 Fleetwood Churchill collected from the literature and his own experience a series of 34 cases of paralysis occurring during gestation and in childbed. Cases of several types are recorded and some of them appear to have been paralyses of cerebral origin. Four cases of lower limb paralysis of the type now under consideration were included in his collection. One of these had been described by Beatty in 1836. The author makes it clear that such paralyses were well recognized in his day. He quotes Campbell as attributing the condition to the long continued presence of the fetal head in the maternal pelvis (Fig. 1). Campbell considered that this was due to disproportion and believed that it resulted in injury to the sacral plexus. Churchill points out, however, that other authors had indicated that the paralysis might follow the easiest labors as well as the most difficult instrumental ones. He also states that Romberg recognized the condition but disagreed with the obstetricians' view that paralysis was due to pressure on the sacral plexus, suggesting instead that it resulted from an accumulation of fluid in the spinal canal. In 1892 Hunermann stated that in these cases the muscular weakness almost always affected the muscles supplied by the external popliteal nerve. He

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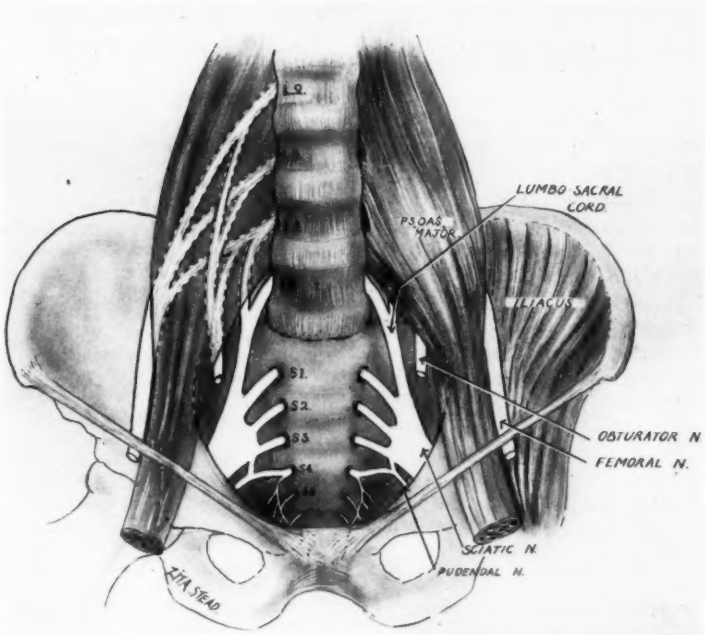

Fig. 1. Drawing showing the relationship of the femoral nerve, lumbosacral cord, and sacral plexus to the bony wall of the true pelvis.

suggested that this was because the lumbosacral cord was injured by the pressure of the fetal head. He considered that the exposed position of this nerve as it crossed the pelvic brim rendered it particularly liable to injury (Fig. 1).

In 1900 Thomas described 2 cases of lower limb paralysis after labor and supported the view of Hunermann. He further suggested that the term maternal obstetrical paralysis be used to describe these cases and distinguish them from the commoner infantile obstetrical paralysis. In 1933 Beattie reported 3 cases and pointed out that in 2 of these the presentation was such that pressure of the fetal head on the lumbosacral cord could not have been responsible for the neurological disturbance. As an alternative he suggested that the nerves might be injured during the application of the blades of the obstetric forceps.

It has thus been widely accepted that these paralyses are due to injury of the lumbosacral cord or sacral plexus by the fetal head or the obstetric forceps. The only alternative explanation encountered in the literature is that of Lambrinudi (1924). This author objects to the view that maternal birth palsy is due to compression of the lumbosacral cord by the fetal head. He points out that the paralysis may occur on the opposite side to that through which the greatest diameter of the fetal head passes during labor and states that any mechanism which explains this rare postpartum paralysis should take into account the commoner antepartum sciatic pains. He suggests that during the latter part of pregnancy and in labor a rotation backward of the sacrum occurs to enlarge the pelvic inlet. This causes traction on the lumbosacral cords and as a result pain of sciatic distribution and less often paralysis appear. It is believed that this author's suggestion of a common causative lesion in sciatica and in paralysis occurring in pregnancy and the puerperium is an important one. Further it is believed that his view that both occurrences result from traction rather

than pressure applied to certain roots of the sciatic nerve is helpful. The usual cause of the stretching of the roots concerned is believed to be a lesion the importance of which had not been recognized at the time of publication of Lambrinudi's paper.

There are several objections to the pressure hypothesis, in addition to those raised by Lambrinudi. In the first place the paralysis may occur when there is no disproportion, when forceps have not been used and when labor is short. Second, as will be seen in one of the cases recorded, the paresis may first appear some days after labor and may then progressively increase for a further period. Indeed in one of the cases mentioned by Churchill the muscle weakness appeared during labor on one occasion and then recurred during a subsequent pregnancy. Third, it is stated in the literature that the paralysis has sometimes occurred in the distribution of the femoral nerve. This nerve cannot conceivably be subjected to pressure from the fetal head or obstetric forceps during labor (Fig. 1). Fourth, since only one oblique diameter of the pelvic inlet is occupied by the greatest diameter of the fetal head it is difficult to explain the occurrence of paralysis of both lower limbs after labor on the basis of compression of nerves within the pelvis by the fetal head. Thomas has described such a case of bilateral paralysis. Finally, it may be pointed out that the lumbosacral cord is to some extent protected by the large iliac vessels, and it is perhaps a little strange that this small structure can be injured by pressure which produces no injury to the larger structures, the bladder and the rectum.

AN ALTERNATIVE HYPOTHESIS

From personal experience during the last few years it is believed that protrusion of a lumbar intervertebral disc is the factor which produces maternal obstetrical paralysis in a proportion, perhaps a large proportion, of the cases. The evidence for this view will now be considered.

Case Reports. The case histories of 4 patients who developed maternal obstetrical paralysis —or more properly paresis—will be given in the first place.

CASE 1. Mrs. E. W., aged 25 years, came to St. Bartholomew's Hospital in March, 1940, complaining of right sided sciatica. She stated that 14 months previously her first child had been born. She had been well during the pregnancy apart from some aching in the right buttock during the latter weeks. Although the presentation was a breech, labor was short and she was delivered of a 5½-pound child. During the labor she had suffered from severe pain down her right leg, which, however, did not persist. When she got up, about a week after the delivery, she noticed some transitory pain in the right calf. One month later severe pain developed in the right buttock, posterior thigh, and calf, and she soon became completely incapacitated by it. Associated with the pain was a weakness of her leg which made it impossible to bear weight on her right toes. There were tingling and numbness in the painful area and spreading downward on to the lateral portion of the dorsum of the foot. During the whole period before she was seen she received a variety of treatments including complete rest in bed in hospital, manipulations of the spine with stretching of the sciatic nerve, and epidural injections. None of these had given any relief. There was no disturbance of sphincter control. She stated that she had always been well and had had no previous attacks of lumbago or sciatica.

Examination revealed a tired emotional woman. There was limited mobility of the lumbar spine and diffuse tenderness of the lumbosacral region. No scoliosis was present. Straight leg raising was limited to 75 degrees on the right and at 80 degrees on the left produced pain in the right leg. There was wasting and loss of tone in the right gluteal, hamstring, and calf muscles and gross weakness of plantar flexion of the right ankle. Sensory examination showed a large area of hypalgesia and hypesthesia over the posterior thigh and calf and outer portion of the dorsum of the foot on the right (1st and 2d sacral dermatomes). The right ankle jerk was absent. X-ray examination showed no abnormality in the lumbar spine but there was a slight relative displacement of the pubic bones at the symphysis. This change is apparently not infrequent in pregnancy. Lumbar puncture gave no evidence of subarachnoid block, the cerebrospinal fluid containing 60 milligrams of protein per 100 cubic centimeters. As the patient reacted rather strangely to the puncture it was decided not to do a myelography—a procedure which was used as a routine at that time. An exploration was carried out on the clinical diagnosis of a lumbar intervertebral disc protrusion. A large protrusion of the lumbosacral disc on the right was readily exposed and removed with a rapid and complete relief of symptoms.

This patient, not unnaturally, attributed the troubles through which she had passed to her pregnancy and before her discharge enquired as to the risk of a similar complication in a subsequent pregnancy. She was assured that the risk was too small to be considered. She remained in perfect health for

18 months until in September, 1941, her second child was born. The pregnancy had been normal and after a short and normal labor she was delivered of a child weighing 6 pounds. She got up a week after labor and immediately developed pain in the right buttock, posterior thigh and calf, radiating on to the outer part of the dorsum of the foot. There was some backache, and numbness and tingling were experienced in the painful areas. The pain rapidly became more severe and becoming completely incapacitated she again presented herself for treatment. On examination the signs were essentially as they had been at the time of the first examination with the addition of a marked scoliosis convex to the right in the lumbar region. She was observed for a period of 6 weeks during which no improvement was evident. At the end of this period exploration was carried out and a further large intervertebral disc protrusion removed from the lumbosacral level. Again there was immediate relief of symptoms and the patient remains well.

CASE 2. Mrs. M.W., aged 27 years, came to hospital in October, 1942, complaining of left sciatica. She gave a long history of backache and sciatica. Twelve years previously she had strained her back during a gymnasium class and developed severe lumbar pain which persisted for some days. Subsequently she had been liable to mild and infrequent attacks of backache. Six years before her admission she developed left sciatic pain after another back strain and this kept her in bed for some weeks. After this it slowly cleared up but there remained a tendency to pain in the limb during damp weather. Again 2 years before her admission she had an attack of lumbago followed by severe left sciatica. On this occasion she was troubled by pain for many months. A year before admission she had a third attack of sciatica—this time right sided. It was relieved after 2 months by manipulation. Soon afterward she became pregnant and was well until the latter part of the pregnancy apart from suffering from occasional cramps in her left leg. Two days before the birth of her child she developed severe lumbago and left sciatica, and she noticed that, during the labor, straining was difficult as it caused severe cramp in the left leg. Labor lasted 9½ hours, no instruments were used, and she was delivered of a child weighing 7½ pounds. After delivery the patient was free from pain until she got up on the 9th day. Low back and left sciatic pain reappeared immediately and became very severe. The pain was of typical sciatic distribution and spread onto the lateral aspect of the ankle. It was aggravated by coughing, straining, etc. and relieved by rest and attitudes of flexion. There was an associated numbness over the lateral margin of the foot and the lateral toes. Two weeks after the onset of her pain she developed weakness of dorsiflexion of her left foot. This became worse for a period of about 2 weeks and then remained stationary. She was greatly incapacitated at the time of her admission 5 weeks after the delivery. There was no sphincter disturbance and nothing of import in the past or family history.

On examination the patient was co-operative and intelligent. There was no lateral tilt of the spine but the normal lordosis was obliterated. Mobility was diminished in the lumbar region—especially flexion and lateral tilting to the right. There was tenderness of the lumbosacral region. Straight leg raising was reduced to 45 degrees on the left and 75 degrees on the right. Both legs could be raised to 65 degrees when dropping the right leg caused an increase of pain. There was atrophy of the left buttock and hamstrings as well as all the muscles below the left knee. Eversion of the foot was paralyzed and dorsiflexion greatly weakened. Some weakness of inversion and plantar flexion was also present. Sensory examination showed a diminution of tactile sensibility and a hypalgesia in the first sacral dermatome. The left ankle jerk was diminished. X-ray examination showed a definite displacement at the symphysis so that one pubic bone was higher than the other. There was no abnormality in the lumbar spine. Lumbar puncture was not carried out, and a diagnosis of a protruded lumbosacral disc was made. At operation a very large protrusion was found at this level. It filled a great part of the spinal canal and the first sacral nerve on the left was greatly swollen. The weight of disc tissue removed was 8 grams. Following operation there was an immediate disappearance of patient's pain and a steady improvement of muscular power. When seen 6 months later she was well in every way, the only residuum of her trouble being that eversion and dorsiflexion of the left foot were still weaker than on the right.

CASE 3. Mrs. E. P., aged 23 years, came to hospital in January, 1943, complaining of pain in her right leg. She stated that 2½ years previously while carrying out her work, which entailed lifting heavy weights, she suddenly developed low back pain. Owing to the persistence of this pain she had been treated in a plaster jacket for some 4 months and afterward wore a leather jacket. A year after the onset of her symptoms she felt quite well again though her back was liable to ache at times, especially during pregnancy.

Nine months before her admission her child was born. Labor was normal, no instruments were used, and at birth the child weighed 8½ pounds. Three weeks later she got up and there was an immediate return of low back pain soon followed by right sciatica. This persisted unrelieved until her admission. It was of typical distribution and involved the dorsum of the foot in its lateral part. The pain was aggravated by exercise and straining and at times patient had got up at night to "walk the pain off." There were associated paresthesias—numbness of the calf and tingling over posterior thigh, calf, and sole. She noticed too that the right leg was definitely weaker than the left so that she stubbed her toes and the ankle "kept doubling under." There was no micturition disturbance, and the past and family history revealed nothing of significance.

TABLE I.—ANALYSIS OF GROUP OF PATIENTS IN WHOM PRESENCE OF LUMBAR INTERVERTEBRAL DISC PROTRUSION WAS VERIFIED AT OPERATION

	Cases
Total number of cases	120
Number of males	81
Number of females	39
Number of female patients who had borne children	9
Number of these in whom symptoms appeared or recurred during pregnancy or the puerperium (78%)	7

Examination showed the patient to be somewhat adipose. There was loss of the normal lumbar lordosis, limitation of movement of the lumbar spine, especially flexion and lateral movement to the left, and tenderness of the lumbosacral region. Straight leg raising produced pain at 35 degrees on the right, and at 75 degrees on the left. When both legs were raised together, pain was caused at 60 degrees and much increased by dropping the left leg. There was 1½ inch of atrophy and loss of tone in the muscles below the right knee. Associated with it was a gross weakness of the dorsiflexors and evertors of the right foot; a degree of contracture had become established so that passive dorsiflexion of the foot was limited. Sensory examination showed hypesthesia and hypalgesia in the first and second sacral dermatomes. Vibration was diminished at the right lateral malleolus and position sense in the right toes was reduced. The right ankle jerk was only just obtainable. X-ray examination showed no abnormality of lumbar spine or lumbosacral region. Lumbar puncture was not performed and a diagnosis of a lumbosacral disc protrusion on the right was made. At operation a well marked protrusion was exposed in this situation, the weight of tissue removed being 4.5 grams. There was a rapid relief of pain and since operation there has been a steady recovery of motor power. When seen 5 months afterward she showed only some stiffness of the lumbar spine and a very slight residual weakness of the foot.

CASE 4. Mrs. D.R., aged 32 years, came to hospital in September, 1943, complaining of low back and left sciatic pain. Three years previously she had begun to experience right gluteal pain relieved eventually by a manipulation. Again 15 months before her admission she developed left sciatic pain after a back strain. It cleared up in a few weeks. In July, 1942, she became pregnant and after a few months she began to be troubled by low back pain. In April, 1943, her baby was born after a normal labor, instruments not being used. She got up 10 days later and immediately developed pain in her left buttock and noticed that the right hip was prominent. The pain rapidly increased in severity and she states that she became greatly "bent up." Physiotherapy and injection treatment were unavailing. For 3 months before her admission she was confined to bed and unable even to care for her baby. At the time of her admission the pain was of typical sciatic distribution and spread onto the dorsum of the foot. It was increased by coughing and other effort and relieved by an attitude of generalized flexion. Paresthesias in the foot were marked and the ankle on the affected side was grossly weak. There was no evidence of sphincter involvement, and nothing of interest in past or family history.

Examination revealed a co-operative woman greatly incapacitated and in constant severe pain. There was a gross spinal deformity, the patient standing with the neck, spine, hips, and knees flexed, and any attempt to overcome the flexion at any of these situations increased her pain. In addition a gross scoliosis was present. It was of alternating type, but most frequently the convexity in the lumbar region was directed to the right. The straight leg raising test could not be carried out since any attempt to extend the knees increased her pain, even though the limb lay on the bed. Increasing the degree of her hip flexion did, however, cause pain. There was well marked atrophy and loss of tone in the left buttock, posterior thigh, and in all the muscles below the left knee. There was gross weakness of movement at the left ankle—dorsiflexion of the foot and toes, and eversion of the foot were most affected but inversion of the ankle was also markedly weak. Sensory examination revealed no definite change, although it was possible that there was some slight blunting of sensation over the lateral portion of leg and foot. The tendon reflexes were not disturbed. Radiological examination revealed narrowing of the disc between the 4th and 5th lumbar vertebrae and that the right pubic bone was above the level of the left at the symphysis. A diagnosis of a protrusion of the 4th lumbar disc was made. Lumbar puncture was not performed. At operation a protrusion weighing 4.75 grams was removed. The patient experienced immediate relief from her severe pain and walked erect 3 weeks after operation. Recovery of motor power is progressing rapidly.

The increased incidence of intervertebral disc protrusion in pregnancy. It is well known that low back and sciatic pain are of frequent occurrence in pregnant and puerperal women. Since a lumbar intervertebral disc protrusion is, in the opinion of a large group of neurologists and neurosurgeons, by far the commonest cause of these symptoms it suggests that during pregnancy there may be an increased risk of such protrusion occurring. The statistics in Table I lend support to this view. These figures deal with patients in whom lumbar intervertebral disc protrusions were demonstrated at operation. Of the 39 female patients, 9 had borne one or more children; of these 9 women 7 had developed symptoms of the protrusion during pregnancy or the puerperium.

Maternal obstetrical paralysis in the distribution of the femoral nerve. It has been mentioned that in some cases of maternal obstetrical paralysis the femoral nerve has been involved. It is impossible for such a lesion to be due to compression of the nerve by the fetal head—unless one assumes that in such cases the nerve has an origin and course unknown to anatomists. The occurrence of signs in the distribution of the femoral nerve is readily explicable on the basis of an intervertebral disc protrusion. In a personal series of such protrusions there are now several in which the clinical picture is that of a so called "anterior crural neuritis"; that is, pain on the anterior aspect of thigh and subcutaneous surface of the tibia and weakness of the quadriceps. Examination shows a wasted weak quadriceps, a diminished or absent knee jerk and an area of hypesthesia and hypalgesia on the anterior aspect of the thigh and leg. In these patients the protrusion is at a higher level than the usual. It may be between the 3d and 4th lumbar vertebrae or at the interval above this.

The occasional occurrence of a paraplegia after labor can be readily accounted for by the occurrence of a very large disc protrusion such as that represented in Figure 2. One patient in the series of 120 had a protrusion of this type and had evidence of a complete lesion of the cauda equina.

DISCUSSION

It has long been recognized that alterations in the structure and mobility of the pelvic joints occur during pregnancy. In modern times understanding of this fact has been augmented by the work of clinicians, radiologists, and endocrinologists. In pregnant women the increase in the mobility of the symphysis pubis, sacroiliac joint, and sacrococcygeal joint has been observed clinically and indeed the Walcher position was introduced in an endeavour to utilize this mobility and thus to facilitate delivery in cases of contracted pelvis.

The pelvic joints have been subjected to x-ray study and careful measurement with varying results. Roberts (1934) has made a series of measurements and comes to the conclusion that during pregnancy there is an average increase in the width of the two sacroiliac joints of 1 millimeter. Further he has found that the average increase in the width of the symphysis pubis amounts to about 2 millimeters. Abramson, Roberts and Wilson (1934) have carried out a similar investigation on the symphysis pubis and conclude that while the average increase in symphyseal width during pregnancy is 3 to 4 millimeters, in 25 per cent of individuals the increase is greatly in excess of this figure. The authors state that the change begins to develop in the first half of pregnancy and does not progress during the last 2 months. They point out that this relaxation of the pubic joints may give rise to disability, and describe a group of 30 cases with symptoms which they regard as being due to increased mobility of the pelvic joints. Young (1940) also describes a group of cases in which he considers symptoms arising during pregnancy to be the result of excessive relaxation of the pubic and sacroiliac joints.

The cause of these changes in the pelvic joints of women has not been decided with certainty. But in lower animals it has been demonstrated to depend upon an endocrine factor. A substance, which has been named relaxin, has been demonstrated in the corpora lutea and serum of certain pregnant animals (Hisaw, 1927). When injected into female guinea pigs during estrus rapid and marked relaxation of the symphysis pubis takes place. A similar substance has been found in the serum of women during the early months of pregnancy (Abramson, Hurwitt and Lesnick 1937). These authors suggest that it is responsible for the characteristic joint changes in women. Indeed, it would be difficult to explain the changes on any but an endocrinological basis, since they begin to appear early in pregnancy. It is also difficult to understand how the action of a joint relaxing hormone can be restricted to the pelvic joints. It seems likely that other joint tissues would respond to the hormone, and it is here suggested as a possibility that changes may be induced in the lumbosacral and other intervertebral joints. It is possible that such changes may be responsible for the fact that in a series of women who had been pregnant and who were later

shown to have protruded lumbar intervertebral discs the symptoms of the protrusion either first appeared or recurred during pregnancy or the puerperium. In 1 patient, as has been seen, an intervertebral disc protrusion appeared in association with each of her two pregnancies. Quite apart from any such hypothetical changes in joint structure induced by pregnancy it is likely that the intervertebral joints in the lumbar region are subjected to stresses by the exaggerated lordosis present at this time. To summarize these remarks, sometimes symptoms of a lumbar disc protrusion appear or recur during pregnancy. This may be coincidental but it is believed that the posture of pregnancy and alteration in intervertebral joint structure may possibly render the pregnant woman prone to develop such a lesion. At other times symptoms of the protrusion arise during or after labor. Here it would seem that the muscular straining of labor is responsible for the occurrence—acting perhaps on intervertebral joints which have already been weakened as a result of structural alteration and abnormal stresses.

When protrusion of a lumbar intervertebral disc occurs during pregnancy or the puerperium 3 different types of clinical syndrome may follow. First, the most frequent result will be—as it is in nonpregnant individuals—the development of backache and sciatic pain. The clinical picture will be that which is now becoming recognized as being due to a lumbar disc protrusion. It has been described in some detail in a recent publication (O'Connell, 1943). The pain is characteristic and the objective neurological findings are likewise definite though not obtrusive. While it is usually present in some degree, actual weakness of muscles or sensory loss will rarely have been noticed by the patient. Here then is the syndrome of symptoms without paralysis. Second, at times paralysis has developed during or after labor and there has been no associated pain. In the majority of reports of cases of maternal obstetrical paralysis which have been encountered pain has been stated to have been present but in some no mention is made of it. This is the syndrome of signs without pain and it is believed that it too may be produced by an intervertebral disc protrusion. It is quite uncommon. Third, there is the group, of which the 4 cases reported in this paper are examples, in which the intervertebral disc protrusion gives rise to both sciatic pain and gross muscle weakness. Perhaps the majority of cases of maternal obstetrical paralysis are in this group.

How can these three different syndromes be each attributed to the same cause—a protruded lumbar intervertebral disc? It is to be expected that the clinical picture which follows a disc protrusion will vary. Further the variations will depend upon the severity of the nerve lesion produced by the protrusion. The common type of protrusion is related to one extradural nerve only and subjects this to a stretch. The dura and the mobile roots contained within it are readily displaced by the protrusion, but the relatively tense and immobile extradural nerve cannot be so displaced and thus bears the full weight of the attack (Fig. 2). The trauma is such that pain is perhaps very severe but nervous function is only slightly disturbed objectively, i.e., conduction in the majority of the fibers in the roots of the cauda equina and perhaps even in the affected extradural nerve is not disturbed. Rarely it happens that a protrusion of large size develops very rapidly. All the roots of the cauda equina at the affected level are subjected to compression and stretching and a complete cauda equina lesion with its characteristic motor, sensory, and sphincteric disturbances has followed. This happened in but 1 patient in a personal series of 120 verified lumbar intervertebral disc protrusions (Fig. 2). The history of another patient is important, however, in this connection. A young soldier had had repeated attacks of severe sciatic pain for years. At first these were on the right but later on the left. After an interval of some months freedom he was seized one morning by severe left sciatic pain. It lasted in this severe form for but a few hours but when it had passed he became aware of inability to dorsiflex or evert his foot and of severe numbness in the leg and foot. An intervertebral disc protrusion weighing 8.5 grams was subsequently removed. It was centrally placed at the lumbosacral interval but was larger on the left side. It is believed

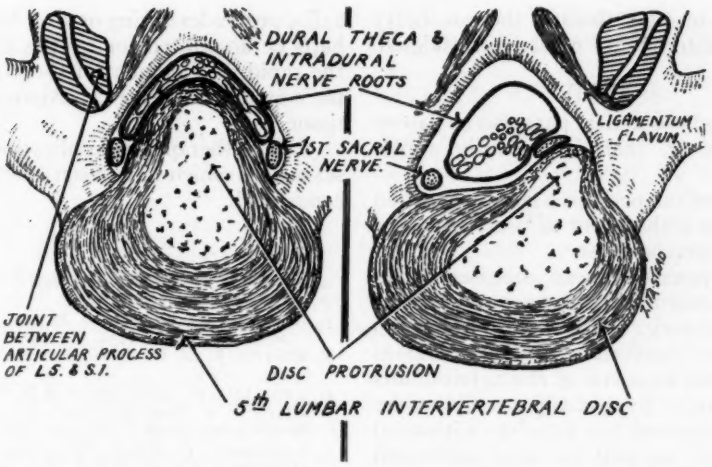
DURAL THECA & INTRADURAL NERVE ROOTS
1ST. SACRAL NERVE.
LIGAMENTUM FLAVUM
JOINT BETWEEN ARTICULAR PROCESS OF L5. & S1.
DISC PROTRUSION
5th LUMBAR INTERVERTEBRAL DISC

Fig. 2. Diagrammatic drawing of a section made through the lumbosacral intervertebral disc. In drawing at left, a large protrusion has occurred, all the related nerve roots—intradural and extradural—are injured and a complete cauda equina syndrome results. In drawing at right, the common type of protrusion is illustrated. The dura and intradural roots are displaced and the effects of the protrusion are confined to the single related extradural nerve which is stretched.

that in this patient a great increase in size of the disc protrusion occurred rapidly. This produced what amounted to an almost complete physiological section of the related extradural nerve and probably neighboring nerve roots on the left side were also injured; his pain was therefore eased but paralysis and sensory loss took its place. These neurological signs show evidence of improvement only after 4½ months. This is to be attributed to degeneration of nerve fibers following severe injury at the time of the rapid enlargement of the protrusion and it is thought that complete motor and sensory recovery can occur here only if and when regeneration of these fibers occurs. Finally it is believed that a disc protrusion of type (as regards size and rate of development) intermediate between the two just described will be productive of the syndrome of pain and paresis which syndrome includes the 4 cases of maternal obstetrical paralysis described in this paper.

These observations point to certain therapeutic conclusions. In the first place it would seem that changes in the lower intervertebral joints in pregnancy and the puerperium render them less fitted to withstand strain. From the point of view of prophylaxis of low back and sciatic pain the strains of heavy work would appear to be contraindicated at such times. Second, it is obvious from the literature and from personal experience that spontaneous cure of maternal obstetrical paralysis frequently occurs. However, it is also clear from the cases which have been reported in the past that recovery may be slow and incomplete. The 4 patients whose case histories have been given had been severely incapacitated and in 3 of them the incapacity was of considerable duration. Operation will be indicated when the motor disturbance is severe and persistent even if pain be slight. On the other hand severe sciatic pain which does not respond to rest, may indicate operation when objective neurological disturbance is mild. In cases which fall into either of these groups, treatment by excision of the disc protrusion can be confidently recommended. In other cases with subjective and objective disturbance of less severity, a conservative attitude should be adopted. This will imply rest in bed for pain, and splinting together with daily exercises and electrical stimulation for paretic muscles. If disability persists after an ade-

quate period of such therapy the possibility of operative interference must be considered.

SUMMARY

1. Maternal obstetrical paralysis or paresis is more common than is generally appreciated.

2. A proportion, perhaps a large proportion of these cases, is the result of protrusion of a lumbar intervertebral disc.

3. There appears to be an increased risk of a lumbar intervertebral disc protrusion occurring in pregnancy. This may be due to changes in the intervertebral joints analogous to those known to occur in the pelvic joints during pregnancy. Such changes would render the joints concerned less fitted to withstand normal stresses as well as those additional stresses occasioned by the posture of pregnancy and by labor.

4. The severe objective neurological disturbance which not infrequently occurs when a disc protrudes during or after labor may perhaps be accounted for by the large size and the rapid development of the protrusion and the consequent severe involvement of nervous tissue.

5. The therapeutic applications of the observations which have been made are briefly considered.

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THE RADIOGRAPHIC EXAMINATION OF THE ANKLE JOINT INCLUDING ARTHROGRAPHY

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THE radiographic examination of any joint is too often thought to be complete when clear outlines of its constituent bones are produced on an x-ray film. It is clinically certain that ligamentous damage is as serious as bony injury and as radiologically certain that further amplication of x-ray technique can demonstrate ligamentous injury. The radiological principles which apply to the ankle are equally applicable to any other joint and should be extended to them. These methods of examination we suggest are necessary before the full information which it is radiologically possible to obtain about a joint has been obtained. There is no suggestion that it is necessary in every case to employ the full technique, but certain groups of cases should be submitted to modified forms of examination. It is the intention of this article to concern itself with these groups and the method of examination rather than to give a summary of the radiographic appearances of the multifarious lesions of the ankle.

For accurate radiography of the ankle we employed, supplementary to the usual views: (1) plain radiography in a standard position, compared with a similar film of the opposite side, for investigation of the syndesmosis; (2) radiography under strain (sometimes described as radiography in the "position of deformity.") The joint was radiographed under a strain appropriate to the ligaments being investigated and supplemented by comparable pictures of the opposite ankle, under similar strain; (3) arthrography—with a diodone compound.

Of these methods radiography under strain gave the most valuable information, and to obtain comparable films of both ankles, pentothal anesthesia was employed in preference to local anesthesia (Hughes, 1942).

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Positioning. The radiographs were taken in four projections but each case was treated individually and in some instances one or two positions were omitted. In positioning the ankle joint some difficulty is experienced in obtaining standard positions, as in the normal joint the asymmetry of the part leads to small deviations from accuracy. The position of the foot is not a correct guide, as in plantar flexion it may take up many positions in relation to the ankle, owing to inversion and eversion, and even in full dorsiflexion this still holds true although to a lesser degree. Furthermore, there are no landmarks in the ankle region for obtaining a true anteroposterior view. These difficulties are exaggerated in the injured ankle because of the inflammatory swelling which to some extent obscures the malleoli. For accurate radiography the knee was placed in the true anteroposterior position and the leg rotated to obtain the desired position.

The four positions used were as follows:—
a. Anteroposterior, 10 degrees, internal rotation. This position is useful in arthrography for showing leakages around the malleoli and extensions upward along the shafts of the tibia and fibula and downward into the peroneal tendon sheaths.

b. Anteroposterior, 30 degrees internal rotation. Films were taken of both ankles in this position as it is the optimum projection to show the width of the tibiofibular syndesmosis. The foot is dorsiflexed. A simple support in the shape of a prism with triangular ends bearing angles of 30 degrees at their bases was made by one of us (J.G.B.), each foot in turn resting on one side of the prism. In practice, if the head of the first metatarsal and the medial malleolus are placed against the prism with the foot in dorsiflexion, a fairly accurate standard position is obtained, and the films of both sides are comparable. This

position shows extensions of the medium into the tibiofibular joint and escape of the medium in cases of rupture of the ligaments of the syndesmosis (Fig 4, a).

c. A lateral or medial projection with the central ray passing through both malleoli so that they are superimposed (bimalleolar view). This is the best position for showing extensions of the joint cavity anteriorly and posteriorly. The subtaloid joint is very well shown.

d. Lateral, with the ankle rotated to throw the fibula behind the tibia (lateral view). This position in some cases shows the extension into the tibiofibular joint better than b and is useful in cases of fracture of the posterior tubercle of the tibia.

It will be noted that b and c are at right angles to each other and a and d almost at right angles. A comparison of a and b will show if extensions upward in the soft tissues lie slightly in front or behind the malleoli.

The problem of diastasis of the tibiofibular syndesmosis will not be completely solved by accuracy of positioning alone, owing to individual variation from foot to foot. This prevents identical films being obtained and thus destroys the absolute accuracy which is necessary if separations measured in millimeters are to be taken as significant. One point, however, is worth emphasizing. It has been stated by Bromer and others (Ashhurst and Bromer, 1922) that in no circumstances is a clear space seen between the tibia and fibula, in the normal foot, and such appearance is to be taken as diagnostic of diastasis. We have several cases on record in which there is a visible space between both bones at the syndesmosis on either side. Its presence is due to the shallowness of the tibiofibular groove and is best shown by the use of the 30 degree inverted position. The best evidence of diastasis in doubtful cases is obtained first by accurately comparable radiography in 30 degrees of inversion of both ankles, which may show a significant widening of the interspace. This is supplemented by radiography with the foot externally rotated and dorsiflexed, which shows a further widening of the interspace, and finally, if the lesion is suspected to be incomplete, by arthrography.

Radiography under Strain. Of the simple methods of investigation this method has provided the most useful information in our hands. The fact that 4 to 5 per cent of normal people show a relaxation of the fibular collateral ligament, allowing rotation of the talus of both ankles on inversion of the foot, renders comparable films of both ankles necessary when the position of inversion is used (Figs. 5, a, b, and c). We have found no similar ligamentous relaxations occurring normally which affect the other positions of strain.

The varieties of strain used and cases for they are of value may be summarized:

1. *Inversion*—(tibial flexion) of the hind foot. Used in cases of suspected damage to the fibular collateral ligament and its most frequently injured fasciculus, the calcaneofibular band. This commonly shows a rotation of the talus of from 5 to 35 degrees. Usually a rotation of 10 to 15 degrees is found; this is secondary to a rupture of the calcaneofibular fibers. If the rotation is greater than this, anterior fibers of the capsule of the joint on the external side and the anterior talofibular ligament are torn. If the rotation exceeds 45 degrees the posterior talofibular ligament is also damaged. It is difficult to state whether it is completely torn as its attachments leave it considerable mobility. Corresponding fibers of the posteroexternal aspect of the capsule are, of course, also torn (Figs. 1, a and b.)

2. *Eversion.* This is used for suspected rupture of the deltoid ligament. In rupture of the anterior fibers (partial lesions) a rotation of 10 degrees may be permitted. In complete lesions a 35 to 45 degree twist of the talus occurs (Fig. 2).

3. *Plantar flexion.* In hyperextension injuries the anterior fasciculi of both collateral ligaments may be torn. In such a case the lower surface of the tibia and the upper surface of the talus lose their congruity. This lesion is a common cause of bimalleolar signs of sprain with a negative radiograph. The bimalleolar radiograph is used (Fig 3).

4. *External rotation of the foot.* This is used in cases of doubtful diastasis and results in opening up the syndesmosis. The anteroposterior radiograph in 30 degrees of inversion is used (Figs. 4, a and b).

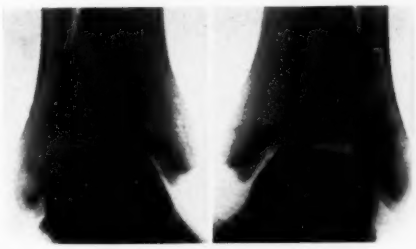


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 1. Radiograph under inversion strain. a, left, Normal ankle. b, Twenty degree rotation of talus, associated with rupture of the calcaneofibular ligament.

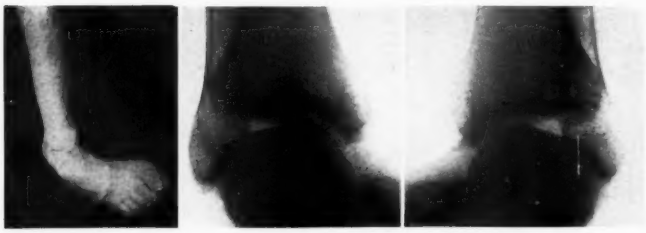
Fig. 2. Radiograph under eversion strain. a, left, Rupture of deltoid ligament; b, The same case showing healing in 7 weeks.

Fig. 3. Radiograph in plantar flexion, showing rupture of the capsule anteriorly, and rupture of the anterior fibers of the deltoid ligament which accompanies severe first degree external rotation fractures of the fibula.

Fig. 4. Radiograph under external rotation strain. a, left, Normal view in 30 degrees internal rotation, showing tibiofibular syndesmosis of sound ankle (left), b, View in 30 degrees' internal rotation of second degree abduction fracture with diastasis, showing opening of syndesmosis under external rotation strain (right).

The essential importance of this method is the distinction between the sprains and complete ligamentous rupture. The more often it is carried out, the more surprised one will be to discover complete ruptures with the minimum physical signs. In cases with bilateral relaxation of the fibular collateral ligament it is necessary to distinguish recent from old lesions, because the presence of this abnormality makes the determination of the degree of damage clinically impossible. We would also like to draw attention to the significance of the frequent occurrence of severe pain over the anterior tibiofibular ligaments. The extensive hemorrhage around the fibula in both cases results in the damaged ligament being diagnosed as lying below the position of maximal pain. In our series this resulted in numerous inaccurate diagnoses. The fact that pain occurs over the anterior tibiofibular ligaments is due to the strain on the syndesmosis produced by the rotation of the talus around a horizontal axis forcing apart the sides of the tibiofibular mortice. This is permitted by the tearing of the calcaneofibular ligament. The anterotibiofibular ligament being the tighter of the two ligaments of the syndesmosis is first sprained and being subcutaneous is easily affected by digital pressure. The calcaneofibular ligament is overlain by the fibula and less accessible to the touch.

The four varieties of strain enumerated were also used in cases of fracture in which it was felt desirable to obtain further information concerning ligamentous damage. An accurate analysis of the severity and distribution of the bruising and the radiological appearances enable one to deduce this clinically if one is familiar with the mechanism of fracture. Investigation did serve to emphasize the fact that the common external rotation fracture of the lower end of the fibula may be merely subperiosteal, show slight displacement, or may be accompanied by considerable displacement with tearing of the anterior portion of the capsule and anterior fibers of the deltoid. The treatment of the fracture must thus be adapted to the ligamentous damage and no single method is satisfactory in all cases.



a b c

Fig. 5. Bilateral hypermobility at the ankle joint. Rotation of talus on both sides in inversion, a condition met with in 4 per cent of uninjured ankles. The degree of rotation varies from 5 to 25 degrees. (Without anesthesia.) a, Photograph to show the abnormal inversion of the sole of the foot. b, The right ankle. c, The left ankle.

ARTHROGRAPHY OF THE ANKLE JOINT

Arthrography has not been developed in the British Isles to the same extent as in America and the Scandinavian countries in spite of a proved, if limited, field of usefulness. There is still a prejudice against the conveying of infection by puncture of a joint cavity, in spite of the harmless results following the thousands of injections which have been made. In those cases, and others not reported here, in which the medium was not satisfactorily introduced into the joint and in arthrography of the knee, no ill effects either local or general have been observed to follow the procedure. The investigation of the ankle joint was undertaken in an attempt to solve the complex mechanical problems presented by ankle injuries, by getting further information concerning ligament rupture. After it had been carried out in a series of typical cases the procedure was then used only in those in which added information was required.

We do not pretend that the method has a wide sphere of use. In our experience more useful information is gained by radiography of the joint under strain during general anesthesia. The results of arthrography, confirming the findings of careful observers who have made postmortem examinations on recently injured ankles, are at least interesting comparative evidence, and bring home some essential and often forgotten points. In a few cases the method is of diagnostic value and gives information otherwise unobtainable, particularly in questions of partial separation of the tibiofibular syndesmosis.

Technique. As a contrast medium, "pyelosil" brand of diodone was used. The amount used was 3 cubic centimeters which was increased to 6 cubic centimeters in some cases with marked effusions of blood into the joint. The introduction of such a small amount into a joint, even assuming it entered the circulation through a fracture, can have no general systemic effects of importance compared with those which might follow 20 cubic centimeters injected intravenously in pyelography. The local reaction is primarily important, and no ill effects were noted; there were no complaints of pain, no swelling, and no alteration in progress which was not attributable to the original injury. This is in conformity with the recognized low toxicity of the drug.

Our cases were all done under general anesthesia, as a preliminary examination under strain was to be made, and comparable pictures of the opposite ankle were often required. Pentothal was always employed. After skin preparation, the anterior aspect of the joint was painted with iodine and a long, fine bore needle was introduced into the joint, without the syringe being attached. On regurgitation of mixed blood and synovial fluid, the medium was injected. In older cases, no fluid regurgitated and it was necessary to rely on the sense of touch alone. Entering through the capsule and contact with the smooth surface of the talus can be appreciated. Striking the joint cavity is not easy if judged from the superficial nature of the joint, and at first some injections below the anterior tendons on the dorsum of the foot were made.

a b c

Fig. 6. The normal arthrograph. a, Position: 10 degrees' internal rotation. Showing the usual rounded extension under the anterior portion of the deltoid ligament. b, Position: 30 degrees' internal rotation. The medium in the synovial extension between the tibia and fibula shows poorly. (Compare Fig. 9b.) c, Position: bimalleolar. Note the indentation made by the tendon of flexor hallucis longus in the posterior aspect of the joint, and the extension of the capsule down the neck of the talus.

The injection can be made to either side of the ankle, the needle being entered at the level of the lower surface of the tibia, just inside the anterior margin of either malleolus. The posterior approach offers greater difficulties, and the risk of damage to the posterior tibial artery and nerve if the posterormedial route is employed. In practice we used either approach, entering the needle on the side away from the area where damage was suspected in order to avoid any risk that spilling might confuse the picture. Following the injection, the joint was manipulated a few times to diffuse the medium through the cavity. The failure to diffuse into the required area may be responsible for some negative findings which should be positive. These cannot be offset entirely by increasing the amount of medium used, as large amounts tend to leak through capsular ruptures and reduce its concentration in the joint, at the same time increasing the number of confusing shadows.

Injections were made at any time from 1 to 7 days after injury in recent cases. In these, capsular tearing was as readily seen on the 1st as on the 7th day. The reduction in swelling which occurs after a few days' rest with the leg elevated, simplifies the injection, though the more distended the joint capsule, the more readily the joint is entered. No observations were made as to the length of time the contrast material persisted into the joint, but satisfactory arthrographs were obtained up to half an hour after the injection, though it is obvious that the sooner after the injection the radiograph is made the better the contrast and definition.

The normal arthrograph. No uninjured ankle was examined, and this account is derived from forming a composite picture from the various normal parts of damaged ankles. The joint space shows as a thin line between the upper surface of the talus and the lower surface of the tibia. The line extends downward in the anteroposterior view to just below the malleoli, rather lower on the outer side. In one case a small fringe of synovial membrane indented the medium on the inner side below the medial malleolus. The anterior sac of the synovial membrane extends forward along the articular surface of the talus and slightly beyond. An extension of this sac may show on the anteroposterior film just below the medial malleolus where it bulges out medially to the tibialis anticus tendon. This anterior sac is best shown in the true lateral projection (c) but in the anteroposterior view furrows due to the extensor tendons may be seen. There is a small posterior sac also best seen in view (c) which is frequently notched by the tendon of the flexor hallucis longus and may show other tendinous indentations. This sac is always situated above the posterior process of the talus (or the os trigonum, if present) and must be distinguished from the posterior sac of the posterior talocalcaneal joint which extends backward along the upper surface of the calcaneus and is below the lateral tubercle of the posterior process of the talus (Fig. 10). This latter sac extends very much further posteri-

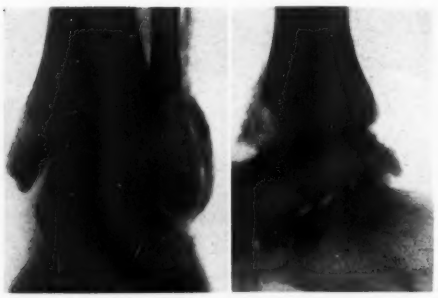


Fig. 7, left. Arthrograph showing rupture of calcaneofibular portion of the fibular collateral ligament, and the narrow neck of escaping fluid between the bone and the periosteum and its attached ligaments (compare Fig. 1).

Fig. 8. Arthrograph (bimalleolar view) showing escape of the contrast medium anteriorly (compare Fig. 3).

orly. Commonly in cases with good filling a small extension upward is seen between the tibia and fibula. This is most clearly seen in b and sometimes in d positions.

Stereoscopy may be of value in some cases to elucidate a particular shadow, but we do not feel that its employment as a routine procedure is worth the extra time and films expended.

The abnormal arthrograph. Arthrography of the ankle demonstrates a number of anatomical facts on the living in a ready and satisfactory manner.

1. Site of rupture of ligaments. The escape of the contrast medium from the joint, around the lower end of the fibula outlines perfectly the shape of the bone and usually runs a short course with parallel, and even borders, before expanding into the subcutaneous tissues over

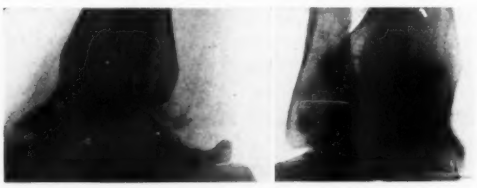


Fig. 10, left. Arthrograph (bimalleolar view) showing conmunication of the ankle with the subtaloid joint and extension into the flexor hallucis longus sheath, and the loose sac of the subtaloid joint extending posteriorly on the surface of the calcaneus.

Fig. 11. Arthrograph of the ankle (lateral view) showing the extension of the medium upward between the tibia and fibula to an abnormal height, suggesting partial diastasis.

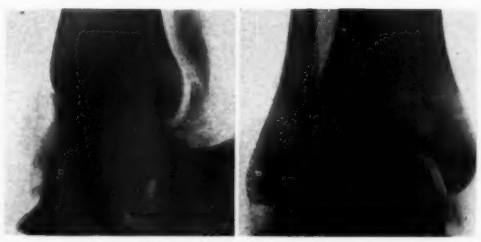


Fig. 9. a, left, Arthrograph showing extension of medium into the peroneal tendon sheaths and into the sheath of flexor hallucis longus. b, Same case showing the extension of the medium into the synovial cavity of the tibiofibular syndesmosis.

the malleolus. This narrow even band represents filling of the space between the torn fibroperiosteal attachments of the ligaments and the bone—well recognized at operation or postmortem as the common site of ligamentous rupture (Fig. 7). We were unable to demonstrate any case in which the medium escaped through the ligament. The common variant is transverse fracture of the malleolus and here the medium escapes through the fracture line. We regard it as highly improbable that a sprain ever results in ligamentous lengthening beyond its elastic limits, i.e., represents scattered ruptures of fibers through the ligament with no break in its contour.

A sprain is due to a partial separation of the fibroperiosteal attachment of the ligament, which alone can account for the rapid and profuse hemorrhage which accompanies even minor sprains.

2. Rupture of the capsule of the joint. This may shed further light on the severity of injury. Thus in first degree external rotation fractures of the fibula the talus and lower fragment of the fibula may rotate backward, thus tearing the anterior capsule of the ankle and finally the anterior fibers of the deltoid ligament. Examination of the amount and site of the hemorrhage allows this to be deduced clinically, and it is confirmed by arthrography (Figs. 3 and 8).

3. Anatomical communication of the ankle joint with the tendon sheaths of the peroneii, tibialis posterior, and the extensor hallucis longus have been recognized as occurring normally (Fig. 9). Their frequent occurrence in ligamentous rupture is well demonstrated

by arthrography. The peroneal sheaths are involved in every case of rupture of the fibula collateral ligament and in almost every case of rupture of its most commonly injured portion, the calcaneofibular ligament. It is impossible from our examination to deduce the incidence in normal ankles, but this is obviously fairly high.

4. Communication between the ankle and the subtaloid joint is also of recognized normal occurrence. It occurred at times in our series, in joints in which it was not specially likely to be produced by injury which suggests the frequency of its normal occurrrence. It is particularly common in cases of partial or complete rupture of the fibular collateral ligament, or injury to the lower end of the fibula (Fig. 10). It is interesting to note that this joint may be entered by introducing a needle between the fibula and the talus until it strikes the dorsum of the calcaneus.

OBSERVATIONS

The traumatic problems to which arthrography offers some assistance are perhaps of a theoretical nature and not to the taste of a practical surgeon. It does give information which is obtainable in no other manner, and it is possible that in a larger series of cases some more interesting and important points would come to light.

1. Diastasis: Complete rupture of both anterior and posterior tibiofibular ligaments can always be determined by accurate radiography without resort to arthrography. In partial diastasis, i.e., lesions involving the anterior or posterior tibiofibular ligament alone, arthrography offers the only available method of proof. In one case (Fig. 11) which would have been regarded as a moderate sprain of the anterior tibiofibular ligament, partial rupture was shown to have occurred. To be of value, it is necessary that the arthrography be carried out early, as the narrow space between the tibia and fibula rapidly fills with clot and blocks the extension of the medium. In certain fractures of the fibula, due to indirect violence applied to the lower end of the bone, only the anterior tibiofibular ligament is ruptured, and, if it is desired to prove this, arthrography must be employed. The field of use is rather restricted, but in this, as in other rare fractures, is a valuable source of additional information.

2. Distinction between old and recent lesions: In the hypermobile ankle which has been the seat of old injury and possibly shows some small flakes of bone in the ligaments, it may be difficult to determine clinically how much of the relaxation of the collateral ligament is due to recent damage (which will respond to treatment) and how much to the old injury. In such a case arthrography is a valuable method of accurately determining the degree of recent rupture present, and so allowing an accurate prognosis to be made.

SUMMARY

1. The technique of arthrography of the ankle is described.

2. The appearances of the normal arthrograph of the ankle are shown.

3. The anatomical features of ankle injuries demonstrated by arthrography are enumerated.

4. Its value in the supplementary examination of ankle lesions is small, and confined to rare lesions, partial diastasis, and the distinction of old and recent injury.

5. More information of diagnostic value can be obtained by radiography of the joint under strain.

6. The appropriate cases in which strain should be employed and the types of strain used are enumerated.

7. The findings are based on 25 cases examined by arthrography.

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THE EXACT ANATOMY AND DEVELOPMENT OF THE LIGAMENTS ATTACHED TO THE CERVIX UTERI

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A GOOD deal of uncertainty and conflict of opinion exists as to the exact attachment and development of the ligaments connected with the cervix of the uterus and their relationship to surrounding structures. As the ligaments are of much importance in gynecological and obstetrical work, it would seem that an understanding of their exact anatomy and development would be of great help in planning operative procedures in this field.

Some of the reasons of misunderstanding may be attributed to (a) lack of unanimity in description in the various textbooks of anatomy and the diverse methods of anatomical demonstration; (b) difference of opinion among gynecologists and obstetricians, both as to their surgical anatomy, and to their function; (c) individual variability in morbid and in normal cases.

Because of the extensive material involved, this study will be divided into three parts.

Part I. The lateral ligaments of the cervix uteri (Mackenrodt).

Part II. The pelvic fascia with its embryological development.

Part III. The clinical significance of the pelvic fascia in obstetrics and gynecology.

LITERATURE

The importance of the connective tissue in the subperitoneal space was almost completely overlooked by the older anatomists.

Virchow originally defined the parametric tissues, as the loose, fatless connective tissues with abundant blood vessels and lymphatics, which surround the lower part of the uterus and the upper part of the vagina.

With the development of gynecology came a keener interest in these fascial structures.

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Acknowledgment and appreciation are expressed to the Cooper Fund of McGill University for a research grant in aid of this work, and to Professor C. P. Martin for criticism and advice during preparation of this paper.

A very stimulating paper on the normal and abnormal positions of the uterus appeared in the *Archiv fuer Gynaecologie* in 1895, by Alwin Carl Mackenrodt, under the caption, "Ueber die Ursachen der normalen und pathologischen Lagen des Uterus." His rise to fame was interesting. He was born November 12, 1859, and died December 29, 1925. Mackenrodt was the son of a landowner near Nordhausen (Harz) who insisted on all his three sons studying theology. Alwin Carl soon defied the old man, "hung theology on a peg," and studied medicine, graduating at Halle with a thesis on Chloasma uterinum. He worked in Volkmann's surgical clinic, started practice in 1886 at Strassfurt and at once made a wide reputation by saving many children by tracheotomy in a severe diphtheria epidemic. In 1890, he went to Berlin as gynecological assistant to August Martin, and started his own private clinic in 1895. Though he refused official connection with the university, his success as a teacher and operator earned him the title of professor in 1904.

A bibliography appended to his obituary lists 73 of his publications, one of which has stood the acid test of time and still bears his name, namely, that related to the present work, in which Mackenrodt summarizing previous work on the constituents of the tissue at the base of the broad ligament, added his own findings. In this paper, Mackenrodt emphasizes the action of a band of connective tissue, which he calls the "ligamentum transversale colli."

Mackenrodt defined it as follows:

"At the side of the vertebral column, the pelvic fascia can be seen to give rise to a strong band which is inserted into the lateral wall of the collum uteri. The small weak center of areolar tissue, between the folds of the peritoneum, in the broad ligament, is sharply to be defined from this fibrous band, which begins at the internal os, and springs from the pelvic fascia. We speak, therefore, of the broad ligament only as the part covering the uterine body, and call

Fig. 1. Lateral ligament of cervix uteri (Mackenrodt) viewed from above presenting superior surface. (Probe under ureter.)

Fig. 2. Right lateral cervical ligament (Mackenrodt) seen from above and behind. Uterus deflected obliquely to left, uterine artery anteriorly. Ureter in position. *1*, Superior surface. *2*, Posterior surface. *3*, Levator ani fascia.

the lateral band to the collum, the ligamentum transversale colli. It is the chief means of fixation of the uterus, and carries in its upper margin the chief artery, the arteria uterina. Smooth muscle fibers extending laterally from the cervix are found constantly in this region.

"As a sort of continuation downward of the ligamentum transversale colli, short fiber bundles spring from the fascia of the levator ani and are attached to the connective tissue sheath of the lateral wall of the vagina, giving it a broader hold. These fibers run in front of the ischiorectal fossa. As a result of this firm lateral fastening of the vaginal canal to the pelvic fascia, the mobility of the lateral walls of the vagina is much less than that of its free anterior and posterior walls, and further, the cross-section of the vagina is fairly constant, and in the resting state, the anterior and posterior walls are in contact. The well known H-shaped folding of the vagina here finds its explanation."

The other features of his paper are as follows: He investigates the factors which hold the uterus in its normal position of anteversion and anteflexion. He described the closure of the anovaginal cleft by pelvic fascia, which sends firm bands to the cervix and vagina. He describes the cervix as being held fast in its embryological position by ligaments, and the normal anteversion and anteflexion takes place by the bending of the cervix—not the corpus. The uterine body is kept in position by its own weight and intra-abdominal pressure, not by ligaments. He supports this lat-

Fig. 3. Anterior layer of left Mackenrodt ligament seen from above and in front. In the picture it appears as if detached from the vagina, but actually it is firmly adherent to the lateral vaginal wall. Bladder—front end retracted.

Fig. 4. Specimen viewed from in front and above. Uterus has been deflected to right. Angular crossing of uterine artery over the left ureter. Ureteric fascia blending with vesical fascia.

Fig. 5. Right anterolateral view of the specimen at a deeper dissection. Lateral cervical ligament (Mackenrodt). Uterus has been deflected to left. Uterine artery crossing ureter at right angles at lateral margin of the superior surface.

Fig. 6. Seen directly from above—lateral cervical ligament (Mackenrodt). Deeper dissection. Uterus to left of midline. Uterine artery displaced posteriorly ureter anteriorly, exposing superior and anterior surfaces of ligament. Cleft in superior surface showing smooth muscle fibres.

ter finding by stating that he has often in the course of a laparotomy, resected portions of the round ligament and retroverted the uterus experimentally, but that he has always found in subsequent examination, in the case of a healthy nonpregnant uterus, that the organ would right itself and be found anteverted again.

While no doubt Mackenrodt did not lack adult material in his private hospital, all of his descriptions with the exception of one, are from fetal pelves, which at their best would not lend to the fullness of description as seen in the adult pelvis. Mackenrodt perhaps, even underestimated the ligament in this respect.

There is considerable diversity of opinion on the anatomical topography and function of the ligaments described by Mackenrodt. Discussion still exists concerning the part which

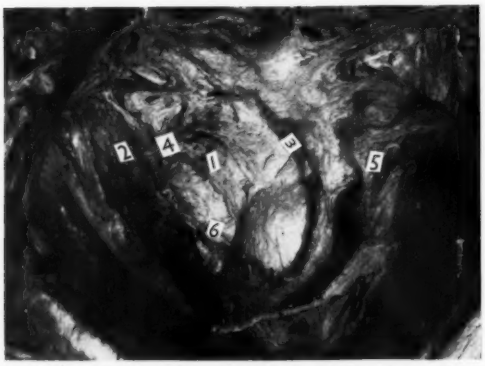

Fig. 7. Seen from above and in front. Deperitonealized, bisected uterovaginal fascia. Vagina is packed and bulging. *1*, Smooth muscle fibres. *2*, Wing-like reflected levator ani fascia. *3*, Uterovaginal fascia. *4*, Ureteric fascial shelf with severed ureter. *5*, Ureter intact. *6*, Perivaginal fascia.

Fig. 8. Seen directly from above. Lateral cervical ligament (Mackenrodt). Uterus and uterine artery deflected posteriorly. Ureter in position. *1*, Superior surface. *2*, Smooth muscle fibres. *3*, Cervicovesical junction.

these ligaments and their juxtaposed fascia play, in the basis of uterine support. Many authors consider the pelvic floor to be the main supporting structure.

Textbooks are not clear on the subject, nor is a great deal of current clinical teaching any more explicit. Modern textbooks in anatomy have been meager, neglectful or vague in their descriptions of Mackenrodt's ligament. Textbooks in gynecology and obstetrics while considering the fascia, have been content with mentioning Mackenrodt's ligament as a part of the general fascial diaphragm, without making any effort to describe it in detail, or have repeated one another's descriptions without personal verification. Leading articles of recent date have featured the fascia, in beautiful semidiagrammatic style, while others have neglected mentioning this important ligament or depreciated its value.

From a review of the literature, it is evident there is still divergence of opinion as to the existence and exact arrangement of this ligament. Anatomical textbooks have been content to recapitulate the earlier descriptions of the pelvic fascia. Recent obstetrical textbooks and papers review its importance in the light of clinical application. Gynecological textbooks and papers in earlier years maintained the concept of this ligament as a purely suspensory apparatus, while more recently, the vascular pedicle as an integral part of Mackenrodt's ligament has been emphasized.

With the object of demonstrating this ligament in a more striking and convincing manner, several special dissections were made.

MATERIAL AND TECHNIQUE

In this contribution, accounts of anatomical dissection of cadavers at different periods of life are presented: two female bodies of 79 and 88 years, respectively, two pelves in midsexual life, one of 25 and one of 30 years, and fetal bodies at various stages of intrauterine life, from 4½ months to term.

The dissected material was injected with a solution of glycerine, alcohol, phenol, formalin and potassium acetate, and was preserved during intervals of dissections, either immersed in injecting fluid, or kept dry in the vault. Some of the fetal pelves were preserved in 10 per cent formalin, others in absolute alcohol. Thus one was able to view both the moist and dry dissections. Plasticine models, to scale, were made from dissected material.

By entering the "clear space" and further separating the anterior and posterior leaves of the broad ligament more caudally, the anterior and posterior surfaces of the lateral ligament are readily brought into view. Figure 1 shows the ligament exposed in this manner and viewed from above, presenting the superior surface. From the lateral to the medial aspect, it can be noted that the uterine artery crosses the ureter at right angles over the extreme lateral margin of the ligament, and then courses medially in the line of cleavage, between the lateral ligament and the vesical fascia. More medially a fascial reef extends from the posterior to the anterior leaf of the broad ligament. It crosses the lateral ligament obliquely and is attached to its upper surface. This reef is instrumental in producing the angular deflection of the uterine artery, and also in deflecting and helping to anchor and maintain the ureter, in its lateromedial approach to the vesical trigone. This feature is of inestimable clinical significance, as otherwise, the ureter would encroach upon the cervix and would be injured more frequently in the operation for total hysterectomy. Thus in reality the lateral ligament of the cervix uteri lies below the uterine artery and ureter.

Turning now and looking at the ligament from a posterior view (Fig. 2), it can be seen that the posterior surface is the largest of the three surfaces and blends with the levator ani fascia. The lateral border of this surface descends from the level of the levator ani white line and proceeding, in a medial and caudal direction, blends with the pelvic layer of the levator ani fascia to a point within a few millimeters of the anovaginal cleft. A particularly firm attachment is present at the ischial spine; this is a "fixation point." In the diagram, the index finger of the gloved hand is placed on the spine. Laterally, attenuated fibers of this surface are continued upward on the pelvic wall to blend with the firm connective tissue which encloses the hypogastric vessels.

Thus, it will be noted, that the lateral fascial attachment of this surface blends with the

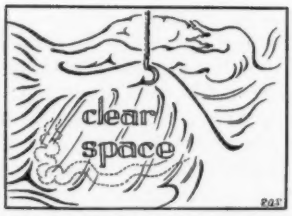

Fig. 9. (Drawing). Clear space.

lateral pelvic wall over a considerable height, giving this ligament a very strong posterolateral attachment and perch, which acts as a wide lateral pliable fixation span. This latter is of fundamental value clinically—when one considers the functions of the ligament from a supportive viewpoint gynecologically, or its clinical value in the physiology of parturition. A very definite foramen is formed at the mediocaudal aspect of this posterior surface, where its fibers blend with the fascia of the levator ani, which is attached to the lower lateral wall of the vagina (Fig. 2).

From the anterior aspect as viewed in Figure 3, it will be noted that the medial fibers of this surface fuse firmly with the fascia on the lateral wall of the upper third of the vagina, while the lateral fibers blend with the visceral fascia of the levator ani muscle. This is the shortest of the three surfaces, because there is an acute rise in the levator ani muscle, in its pubococcygeal fibers in this area.

OBSERVATIONS FROM STUDY

The lateral ligament of the cervix uteri (Mackenrodt) is therefore, a well defined fascial connective tissue capsule, which in transverse sections has the form of an inverted U, originating from the anterior, superior, and posterior marginal walls of the supravaginal cervix with attachments to the vagina. It consists of a superior, anterior and posterior surface.

The superior surface (Figs. 1, 4, 5). The fibers passing posterolaterally in a gentle curve insert into the levator ani white line. (White line of the pelvic fascia for all practical purposes considered conjointly.) Guided obliquely and medially over the lateral margin of this surface by an oblique fascial band (Fig. 1) from the posterior to the anterior leaf of the broad ligament, the ureter runs toward the vesical trigone about a half to three quarters of an inch from the lateral cervical margin on the right side and about half an inch on the left side (Fig. 5). At the extreme lateral margin of this surface, the uterine artery crosses the ureter at right angles and following the anterior margin, traverses the superior surface of the ligament to the supravaginal cervix, where it divides into ascending, lower uterine segment and cervical branches; the latter piercing the ligament.

The veins encapsulated in pelvic fascia are on the posterior aspect of the superior surface. The uterine artery is an individual entity near the anterior aspect of this surface, demarcating the line of cleavage between the lateral ligament and the adjacent cervicopubic fascia (Fig. 1).

Toward the lateral third of the broad ligament, a fascial laminated sheath spreads obliquely from the posterior to the anterior leaf of the broad ligament. This fascial reef is instrumental in deflecting the ureter and uterine artery to the anterior aspect of the superior surface.

The anterior surface (*Fig. 3*). This appears usually to be of a thinner texture and has a smaller surface area than the other two surfaces. Its fibers are directed laterally and caudally to terminate in the levator ani fascia. Here the levator ani muscle rises sharply from a narrow line. The upper medial third of the ligament, with the anterior border of the superior surface, forms an elliptical incomplete hiatus for the passage of the ureter (Fig. 6). The uterovaginal fascia (cervicopubic) blends with this surface (Fig. 7).

The posterior surface (Fig. 2). This is the best defined and largest surface area. Its fibers extend posterolaterally and caudally to blend with the levator fascia. Its most posterolateral extremity is fixed at the ischial spine. Smooth muscle fibers extend from the upper third of the vagina (Figs. 7, *1;* 8, *2*) and insert obliquely into the inferior and medial aspect of the superior and posterior surfaces of the ligament (Figs. 7, 8).

Thus the three surfaces of this ligament enclose a space which in the normal adult contains areolar tissue and smooth muscle fibers.

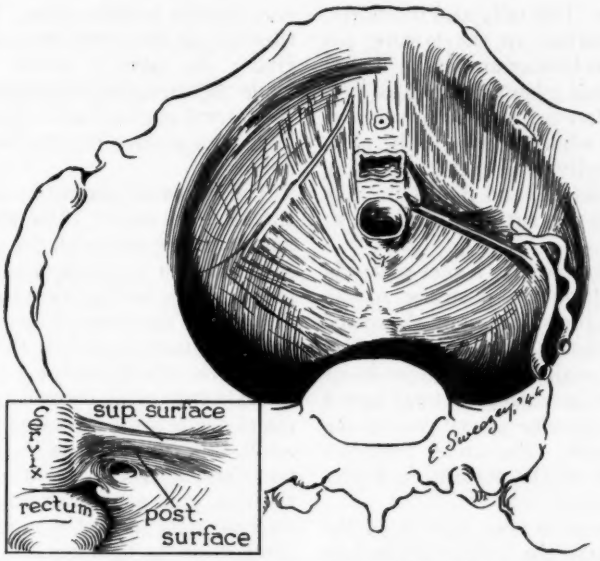

Fig. 10. Semidiagrammatic representation of pelvic floor with right lateral cervical ligament shown in position. (On the left side the fascia has been removed to show the underlying muscles.) At the lateral end of this ligament the uterine artery can be seen crossing the ureter. At the medial end of the ligament the inverted U-shaped outline is well shown. The small insert shows the ligament from behind. Note the hiatus at the lower border of the posterior surface—for further description see text.

Looked at from in front, this space is triangular. The base of the triangle facing caudally and lateralward is formed by the superior layer of the levator ani fascia.

On account of its inverted U-shaped structure, the ligament is capable of great expansion by an opening out of its anterior and posterior surfaces and thus is able to meet physiological requirements.

METHOD OF APPROACH (FIG. 9)

The simplest method of approach to expose the lateral cervical ligament is to secure the utero-ovarian ligament, the tube and round ligament, and open the broad ligament completely down to the bottom of the clear space. The anterior and posterior leaves of the broad ligament are then readily separated, exposing the uterine artery and superior surface of the lateral cervical ligament.

Few other structures in the human body have enjoyed such a varied nomenclature. Among others, the following designated titles have been applied: the parametrium (Virchow), the cardinal ligaments (Kock), the vascular sheath (Charpy), hypogastric sheath (Pierre Delbet), the uteroiliac process (Savage), transverse cervical ligament (Mackenrodt), tunica vasorum uteri (Merkel), ligamentum lata, lateral pelvic ligaments, ligamentum transversale colli, the sustentacular apparatus (Bonney), the lateral cervicopelvic ligaments.

The anglicized version, namely, "the lateral ligament of the cervix uteri" is a more meaningful and purposeful terminology, and in keeping with the principles accepted at Basle, in 1895, by the Anatomical Society.

SUMMARY

Figure 10. A well defined fascial ligamentous connective tissue capsule in the form of an inverted U is attached to the anterior, superior, and posterior marginal walls of the

supravaginal cervix. Laterally and inferiorly, this capsule is attached to the levator ani white line and to the levator ani fascia. It has anterior, superior and posterior surfaces.

The *superior surface* presents large veins on its posterior aspect while anteriorly, the uterine artery is an individual entity, coursing above the fascial surface, and marks the line of cleavage between this surface and the vesical fascia.

Toward the lateral aspect, a reef of fascia extends obliquely from the posterior to the anterior leaf of the broad ligament above the capsule and deflects the uterine artery anteriorly and helps to maintain the ureter in its lateral position. At the extreme lateral aspect of this surface, the uterine artery crosses the ureter at a right angle. The ureter traverses the anterior margin of the surface, in a preformed fascial groove.

The *anterior surface* is the smallest of the three surfaces, because the levator ani muscle rises sharply in this region. The upper part of this surface fuses with the uterovaginal fascia giving the latter a wider "fixation span," while the lower part is attached to the fascia of the lateral vaginal wall. Caudally and laterally, this surface is attached to the levator ani fascia.

The *posterior surface* is the largest of the three surface areas. It blends with the levator ani white line and with the levator ani fascia. A foramen or gap is present between the ligament and the fascial fibers passing up from the levator to the vaginal fascia. A triangular space exists between the three surfaces. The base of the triangular space faces caudally and lateralwards being formed by the cranial fascia of the levator ani muscle. In the normal adult this cavity contains areolar tissue and unstriped muscle. Smooth muscle fibers extending from the upper third of the vaginal wall are attached to the superior and posterior surfaces of the ligament.

RECONSTRUCTION AFTER RADICAL OPERATION FOR OSTEOMYELITIS OF THE FRONTAL BONE

Experience in Thirty-eight cases

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THIS paper is a compilation and review of 38 cases of patients who have been operated upon in the past few years for the correction of cranial defects following previous operations for osteomyelitis of the frontal bone. It is a continuation of the series reported 3 years ago by V. H. Kazanjian and J. M. Converse. The authors then discussed the operation for osteomyelitis and also the problem concerned with plastic repair. In this paper, no attempt will be made to discuss the problem as a whole or as it relates to osteomyelitis of the frontal bone, as the problems have been adequately dealt with by other authors (8, 10, 12, 14, 15, 16).

In the present series, the authors were presented with the problem of dealing with the surgical end-results of osteomyelitis; that is, operation had been done to remove the osteomyelitic bone and the patients had recovered but they were left with varying degrees of scarring and disfigurement. In the least disfigured patient there was found scarring along the lines of incision used to expose the frontal bone in association with a flattening of the supraorbital ridge and forehead from the loss of bone (Case 1, Fig. 6). In the most disfigured patient the defect had been caused by the forehead flaps being permitted to retract, and thus to become folded or corrugated. The dura then became exposed and coated with a thin layer of epithelium so that such patients were truly disfigured individuals (Case 2, Fig. 9). The various methods employed in repairing the defects in the latter group of patients, the changes in the form of treatment from that used in earlier cases of osteomyelitis and some of the pitfalls that have been encountered will be discussed.

From the Plastic Clinic of the Massachusetts Eye and Ear Infirmary.

Various implants have been employed at operation—cartilage, bone, vitallium, tantalum, and an acrylic. Each material has its merits, and each one is preferred in specific instances. These materials will be discussed in relation to their value and drawbacks, and an attempt will be made to evaluate as a whole the problem of implants.

INCISION FOR EXPOSURE OF FRONTAL BONE IN CASE OF OSTEOMYELITIS

When a surgeon is contemplating operating on a patient with osteomyelitis of the frontal bone, he should choose the incision that will leave the least disfigurement in the case at hand. In the past, the operators in our clinic have employed an inverted T incision to expose the frontal bone (Fig. 1) which consisted of a midline vertical cut from the glabella to the hairline and a hoirzontal cut just above the eyebrows. The incision gives direct exposure of the forehead when the flaps are reflected and an easy approach into the ethmoid and nose. The midline scar is not difficult to repair and may largely disappear. The main drawback to this incision is the distortion which is prone to occur about the brows—a major problem in restoring the normal countenance. Nevertheless, it is the incision of choice if the case is one of fulminating osteomyelitis which has not responded to chemotherapy and in which the wound must be left open for observation. In such a case the resultant scar is of secondary importance.

When the case is one of subacute osteomyelitis or one in which the osteomyelitis has been controlled by drugs, the operator is then justified in planning an operation that will leave the least disfigurement; in such cases, the operator can plan to expose the bone, remove the diseased area, and return the periosteal flap immediately.

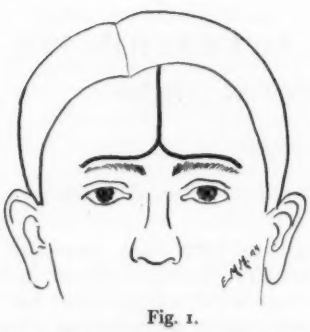

Fig. 1.

Fig. 1. Drawing to illustrate the preferred incision—the inverted T incision with rounded angles—above the eyebrows.

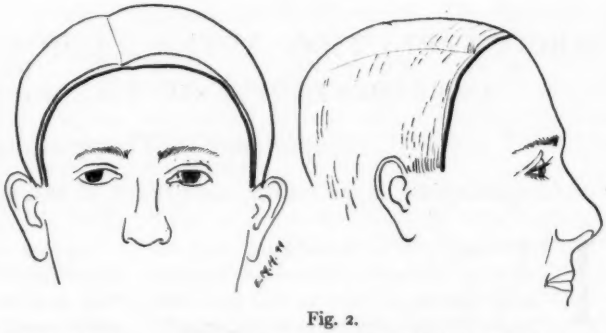

Fig. 2.

Fig. 2. Drawing to illustrate the inverted U incision, which extends from a position just above the ear at the hairline, over to the opposite side.

The incision of choice in such a case is what we call the inverted U incision (Fig. 2). It should start on a level with the top of the ear at the hairline, and follow the hairline over the brow to the opposite side. The scalp may then be retracted forward over the face so that the frontal bone, including the supraorbital rims, is exposed as in postmortem dissections. Even the nasal bones and if need be the lacrimal bone may be exposed in this manner. Through this field, it is possible to do any of the surgery that may be required for the rectification of the osteomyelitic bone and the disease in the frontal sinuses and the ethmoids.

If the operator believes that the operative field should be under observation for a few days, this is also possible. The flap may be left open and, if it is found that the wound is healing properly, it may then be closed. This procedure has been tried and found to work satisfactorily.

SELECTION OF TIME FOR PLASTIC OPERATION TO CORRECT DEFORMITY

Before plastic procedures in these postoperative osteomyelitic cases are undertaken, it is essential that we select carefully our time for operating. The operator must be sure that the patient is completely free of any infection in the bone, the soft tissues, or in the sinuses which originally were the cause of the infection. The second criterion is to be satisfied that the individual has no evidence of intracranial pathology which might be connected with the original infection. In this particular, the operator should be concerned especially with latent brain abscess. Infection in the soft tissue or in the brain cannot be ruled out until at least 2 or 3 months have elapsed following apparent cessation of all inflammatory reactions. If outwardly there is no evidence of infection, the nose should be carefully examined to ascertain the presence of inflammatory reaction or pus, and an x-ray film of the sinuses should be studied for evidence of residual infection. In spite of this care, we have encountered encysted pus and have had infection follow in the wake of an apparently aseptic operation. With infection ruled out to the best of one's ability, it is then comparatively safe to proceed with the operation.

OPERATION; PREPARATION OF FOREHEAD FLAPS

The success of operation depends largely upon the condition of the soft tissues, particularly of the skin and scalp, and to a lesser degree upon the size of the bony defect. If the scalp flaps are not sutured together at the time of removal of the bone, contracture always takes place, and there is a great deal of change in the subcutaneous tissues and in the dura (Case 2, Fig. 9). In such a case, it is necessary to free the flaps from the dura and to stretch them to the size of their original surface area. The operation may be performed either under local or general anesthesia. It is usually more satisfactory to employ general anesthesia. To facilitate the

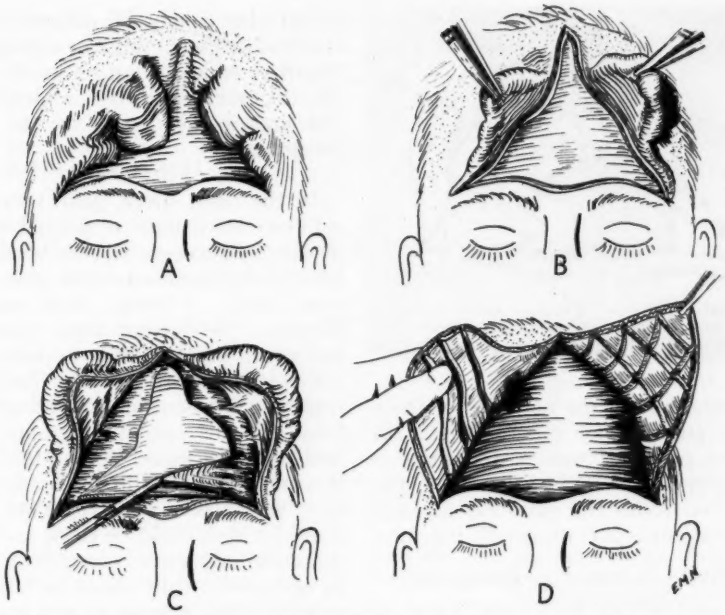

Fig. 3. A, Wound of 3 months after resection of the frontal bone. B, Skin flaps dissected back, exposing the surrounding bone; superficial epithelium incised. C, Epithelium dissected over the layer of granulations covering the dura. D, Incisions carried through subepithelial tissue to permit extension of the skin flaps.

separation of the flaps from the dura and to control bleeding, which is usually considerable when the scalp is involved, it is advisable to infiltrate the flaps subcutaneously with a solution containing a small amount of epinephrine. Epinephrine acts in a twofold manner; it not only reduces the bleeding, but it creates a line of cleavage which makes much easier the separation of the flaps from the dura. Once the flaps have been separated from the dura, they are invariably curled upon themselves or corrugated as a result of the contraction of the elastic fibers and scars in the subcutaneous layers. To enable one to return such contracted flaps back to their normal surface-covering area, it is necessary to cut through the contracted subcutaneous tissue by crosshatching the under surface with a sharp knife (Fig. 3D). When this procedure is carried out, the skin can be approximated without tension. Should the flaps require much crosshatching, it is wise to permit them to heal for from 4 to 6 weeks prior to the grafting of any bone. This period enables the vascular supply to this area to become re-established thus improving the chances of the graft to take. At this step, it is not only customary to free the flaps, but to undermine the scalp over the skull for a distance of 2 to 3 inches beyond the defect, thus assisting in increasing the mobility of the parts involved.

In this type of patient, there is always an area of dura which is covered with a thin layer of epithelium which has grown in from the edges of the wound and must be removed by sharp dissection. If any of the epithelial cells were left, there would exist a potential cyst. Caution must be employed when dealing with the area about the nasofrontal duct; in this area it is easy to enter the nose and to contaminate the field. Should this area be entered, it is advisable to swing a flap of tissue from the adjacent structures to cover this defect. Another precaution that must be considered is the ease with which the orbit may be entered when the brow is freed from the

Fig. 4. Illustration showing the periosteum of the frontal bone cut about an inch and a half beyond the margin of the defect, elevated, retracted medially, and sutured to the dura.

orbital periosteum. In the majority of these patients, the supraorbital rim together with the floor and posterior wall of the sinus is completely gone, so that, in this region, the periosteum that forms the outer casement of the orbital contents is in contact with the dura.

PREPARATION OF BED FOR RECEPTION OF GRAFT

If the flaps were closed at the time the osteomyelitic bone was removed or soon following the original operation, the stage mentioned may be omitted, as the forehead flaps readily cover the defect and there is no epithelium on the dura that requires removal. Our task resolves itself into the preparation of a bed for the reception of a graft or insert.

The flaps are infiltrated as previously mentioned. Incisions are made along the line of the existing scars, and the scalp is separated from the dura by sharp dissection. When the edge of the bone is encountered, the scalp is separated from the periosteum for a distance of 2 or 3 inches around the margin of the bony cavity. The periosteum is incised parallel to the edge of the bony defect and about an inch to an inch and a half from it. It is then separated from the bone and brought toward the center of the defect where its cut edge is sutured to the dura with a few interrupted fine catgut sutures; it is left attached at the margin of the bone defect (Fig. 4). This step may help to fill the cavity and increase the vascularity of the area. The tissue of the brow and bridge of the nose is then dissected carefully down to any bone that is beneath. If it is absent this cannot be accomplished and individual judgment must be employed as to the extent to which the dissection is carried. All bleeding points must be completely controlled. The area is then ready for the reception of the graft.

INSERT MATERIALS

In the past, silver, gold, ivory, steel, and celluloid have been employed with varying degrees of success. On the whole, they have been unsatisfactory because they have caused some degree of foreign body reaction in the tissues. The foreign body reaction, as we know it, is an attempt to remove the material which is incompatible. The ideal material for replacing lost bone in the skull would be living bone. If this cannot be employed the next best material would be one that first, would be completely inert in the living tissues; second, would be no heavier than the bone removed; third, could be thick enough to obliterate all dead space; fourth, could be altered at operation; fifth, would be firm; and sixth, could readily be made in any hospital laboratory. We now have at our disposal 5 substances which are on the whole well tolerated in this area. They are bone, cartilage, tantalum, vitallium, and plastics.

Bone. Bone, of course, answers most of the criteria for an insert material. It can be obtained in sufficient quantities from the patient involved to replace that lost in the removal of the frontal bone. It forms a good, firm, protective coating, and when in contact with the undisturbed bone, forms a living union and tends to retain the characteristics it had prior to transplantation. Roentgenograms of these grafts will show evidence of decalcification in many of them, and yet this does not indicate that they have not taken well. It may not be possible to restore the lost bone at one operation if the area is extensive, but by successive grafts the goal may be reached. The donor areas for this purpose are fundamentally two in number, the front face of the tibia and the crest of the ilium, though other operators might prefer different sites.

Bone taken from the front face of the tibia includes the entire width of the bone which may be 3 to 5 centimeters. It can be as long as is required which may be up to 12 or 15

centimeters in length. The thickness of this transplant depends upon the thickness of the cortex of the tibia but can usually be made from 3/16 to ¼ of an inch thick. This broad, flat, smooth bone can be bent by grooving its under surface with saw cuts and its margin can be curved with either rongeurs or a saw. When such a strip is placed in contact with the freshened margins of the bony defect and held in place by the overlying scalp and a pressure bandage, it has a very good probability of living.

It has been our experience that this tibial graft offers results more pleasing than other grafts. It creates a firm, resistant, protective covering, comparatively free from irregularities.

Bone taken from the anterior portion of the ilium is somewhat more difficult to obtain in a long, broad, flat piece, though in certain cases this is possible. It is easy to obtain in thin, narrow strips, and may be placed over the dura by overlapping the strips as one would shingles, being sure that their ends are in contact with the margins of the frontal defect. Bone inserted in this manner has taken well and given excellent protection, but is prone to result in an irregularity of the overlying skin (Fig. 5).

Cartilage. Cartilage also approaches the ideal insert material. It does not set up a foreign body reaction as it is a living material, it can be built up to minimize dead space, and can be altered at operation. Cartilage may be obtained in sufficient quantities from the costochondral margins of the host to fill in most of the cranial defects that we see. Being a comparatively inert living substance, gaining its nutriment by diffusion, it is an easy material to graft and usually takes very well.

It does, however, have drawbacks. It cannot be obtained in strips long enough to extend from one end of the defect to the other. If it could be so secured, it would be unsatisfactory as it has a tendency to curl. This would not only create an irregularity of the overlying skin, but might create undesired pressure inward.

Cartilage has been employed in the form of small chips (17). Utilized in this form, it is sprinkled into the defect, smoothed out, and then the skin is permitted to hold it in place. In this manner, it is apparently satisfactory for small defects but would not give the protective covering that is desired for large areas of exposed dura. Cartilage does not form an integral part as will bone and is, therefore, best suited for creating a contour of the brow on top of a bony transplant. For such a use it adapts itself well.

Fig. 5. Patient in whom several strips of iliac bone were utilized for the repair of a large defect of the frontal bone. Postoperative recovery was good but there resulted an irregularity of the contour of the forehead: one of the most pronounced types of irregularity in the series we observed. In such cases it is often necessary to re-expose the bone months later and trim the irregular surface with a fine osteotome.

Metals as inserts. Metals have been utilized by surgeons since the 17th century for the filling in of bone defects. In 1665, Petronius (22) employed gold for the repair of a cleft palate. The first use of metals to be applied to fractured bones was in 1775, when Lapeyode and Sicre (22) wound metal wire around a fracture. A little later, in 1826, Rogers (22) of New York, used silver wire in fractures. From that time forward, various metals were advocated and used in all branches of surgery. The drawback of all these metals was that they either set up a galvanic current when in contact with the body fluids, or there occurred a slow process of oxidation about them. For the past century, therefore, various workers have sought to secure a metal or an alloy that was nonelectrolytic, and that was inert in the body fluids. Since 1920, there have been many experiments along this line, and it was definitely shown that electrolysis of the metals was the

Fig. 6a.

Fig. 6b.

Fig. 6. Case 1. The entire frontal bone is missing. Flaps in place show a marked depression and irregularity of the forehead. Note that the eyebrows are good as the incision is above them and not through them.

Fig. 8a.

Fig. 8b.

Fig. 8. Case 1. Postoperative result following insertion of solid thick vitallium plate, which obliterates any dead space. Note the smooth contour in both profile and front view.

disturbing factor when they were used in relation to the living tissues, and at body temperature (5, 21). It was also found that the extent of the tissue reaction and damage was roughly equal to the galvanic action of the metals. This galvanic action is particularly marked when two dissimilar metals are employed in an alloy. When experimenting along these lines, the dental alloy vitallium was utilized and found to be quite inert, which was somewhat surprising because it is an alloy. It was first used clinically in the form of bone screws by Venable and Stuck in 1936. Investigation of metals is still being conducted, and there may be new alloys that will have advantages over vitallium.

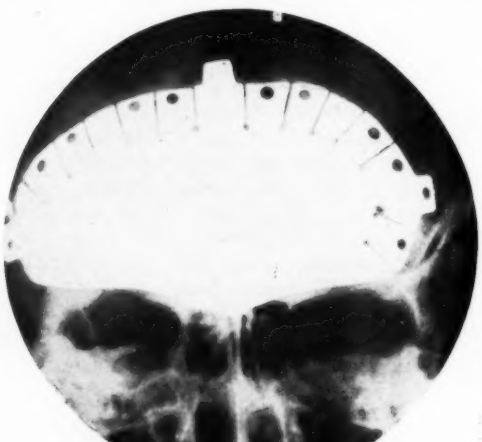

Fig. 7. Case 1. Solid vitallium plate with flanges, in place.

Vitallium. Vitallium is an alloy of cobalt, chromium, and molybdenum, is hard, brittle, and nonmalleable. If thin it can be bent slightly but it is too hard to cut or file with ordinary hand tools. Whenever we wish to employ this metal, it must be cast into the exact form to be used, as very little changing of its shape can be conducted at the time of the operation.

To create a vitallium plate, a model as nearly exact as possible must be made. If an impression can be made of the defect left at the time of the removal of the osteomyelitic bone, it will be an exact fit. The only alteration that might occur in such a bed which would alter the fitting when we wish to insert a plate would be the ingrowth of bone from its margins, and this can be taken into consideration in making the plate. The next stage at which a model may be made is when the flaps have to be elevated, freed, and approximated. At this time the bony defect will have its final shape and an impression made then would not have to be altered. It usually becomes necessary to estimate the shape of

the model by constructing it over a cast of the healed wound. When this is done it is necessary to allow for the thickness of the skin. However, a good approximation can be obtained so that when thin flanges are attached to the outer surface at the periphery, they may be bent slightly at the time of the operation to compensate for variations in contour. The prepared model is then sent to a laboratory with facilities to reproduce it into cast vitallium. It is advisable to have perforations through the thin areas of plate to permit interchange of fluids and ingrowth of tissues.

To insert the plate the bed is prepared as previously described. The plate is then fitted into the defect by bending the flanges to correspond to the contour of the skull. Two or 3 screws are next inserted to immobilize it and the flaps reapproximated.

Vitallium is also made in prepared flat strips of varying lengths. They measure approximately 1 millimeter thick by 5/8 of an inch wide, by 2, 3, or 4 inches long. Each strip has holes in the four corners to permit fastening it to the skull. In selected cases these strips may be used to advantage and will be discussed later.

Tantalum. In recent years, there has been produced the element, tantalum, in sufficient quantities to permit its use in surgery. Tantalum is practically inert, not only in the laboratory but buried in the living tissues (1, 2, 6, 9, 18, 19). It is the 73rd element in the periodic table; it is strong, tough, malleable, and can be drawn and machined. It is soft enough so that it may be cut, filed, and sawed with hand tools. It is, however, difficult to drill except with a slow drill, as it apparently crystallizes by the heat of drilling, becoming very tough. By use of a punch, this difficulty is readily overcome. A formed plate of tantalum may be made by placing a sheet of the metal over a negative cast of the model (4). Over this is placed a rubber pad, and by exerting pressure on this the metal flows into the desired shape. It may then be trimmed and perforated by hand tools. At operation further shaping may be carried out, additional flanges may be cut where necessary, and the edges trimmed. If a method of creating sufficient pressure is not available, the plate may be formed by hammering the tantalum sheet as one would hammer sheet silver or copper to fashion trays or the like. Once approximately formed, the plate may then be inserted to replace the lost bone. The ease with which tantalum may be altered at the time of operation makes it possible for the operator to adjust the plate to a more exact fit than can be done with vitallium.

Tantalum cannot be cast as yet, and is too soft a material with which to make screws, so that it becomes necessary to use vitallium screws or a suture to hold these plates in place. The probability is that there will be a negligible electrolytic process set up between them, and no reaction around the screws should result as both metals are nonactive.

Plastics. Under the term "plastics" are grouped substances which may be molded. This, of course, encompasses a large variety of materials. Those with which we are concerned are grouped under the acrylics, the basic one being methylmethacrylate. One form of this is known as "plexiglass," another one "lucite," depending upon the company which produces the material. It has been found that this material is well tolerated in living tissues (7, 20). It is firm, strong, can be cast, and after heating can have its shape altered. It can be filed and drilled with hand tools. Theoretically it has the advantages of the metal plates plus the fact that it is not radiopaque, so that an x-ray may be taken through it to determine the condition of the underlying structures. It has an added asset in that it is comparatively light and a thick cast will be lighter than the bone it replaces. Plates of this material can be made by anyone familiar with the formation of dental plates. All that is necessary is to have an exact model of the desired plate.

OBSERVATIONS FROM STUDY OF 38 CASES

When we are presented with a lost brow or a small defective area in the skull, which is not more than 2 or 2½ inches in diameter, it has been found that the utilization of a bone transplant is most acceptable. When the dura is covered with bone and it is merely the brow that has been lost, either bone or cartilage may be employed. It seems more advisable

Fig. 9. Case 2. Preoperative defect in patient with entire frontal bone and supraorbital ridges removed. Flaps not sutured. There is retraction and curling of the flaps and a thin epithelial coating over the dura.

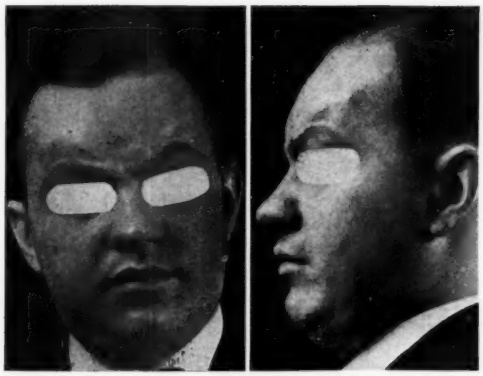

Fig. 10. Case 2. Postoperative result following the use of a perforated vitallium plate. Note that the contour is good and that there is but slight distortion of the brows.

to use bone to replace lost bone, even in this situation, and it has proved to be best in our hands.

If a case presents a defect larger than 2½ or 3 inches, it may be advisable to employ one of the materials that we now have at our disposal. When a preformed plate is used, the operating time is reduced tremendously, as is the operative shock to the patient. This improvement is made possible by the elimination of one entire operation, that of obtaining the bone or cartilage graft.

In each of the cases in which one-half of the frontal bone had been removed, a bone graft was employed to fill in the defect. The support in each case was satisfactory and the cosmetic result, though not perfect in all cases, was greatly improved. In the majority of cases in which bone grafting was employed, there was some resulting irregularity of the skin overlying the graft, and this was more pronounced when iliac bone was used. This irregularity was largely obviated by the use of the smooth plates.

There were other cases in which the entire frontal bone had been removed. In some of these, it was possible to cover the defect satisfactorily with but one bony transplant. In others, it was necessary to employ 2 or 3 successive transplants. In addition to this, in 3 cases a dermal graft was inserted over the bone insert to smooth out irregularities and further raise the brow. It was found that this improved the appearance remarkably for some months to a year but that the fat had a tendency to be absorbed, so the original improvement was somewhat reduced. There was no evidence of cyst formation due to the buried basal layer of the skin.

Not infrequently the bone of the tibia may be quite brittle. This is particularly true in adults. In this state it is prone to fragment when it is removed by means of an osteotome. This may be overcome by utilizing a circular saw. Should it fragment, the periosteum will hold the majority of the fragments together, so that the main transplant may be carried out as though the desired strip had been obtained.

Following the transplant, it is imperative to look for a collection of serum or blood about the graft, and if this occurs it must be evacuated immediately. Such a collection can occur in spite of drainage and a proper pressure bandage. Infection is always a potential cause of failure in these postoperative osteomyelitic cases for three main reasons: first, there is nothing but fibrous tissue separating the nose from the operative field, and this tissue can be readily invaded by organisms from the nose; second, a small cystic mass is occasionally encountered in the scarred tissues which may contain dormant bacteria; and third, the tissues with which we are dealing are quite scarred and their resistance to infection is reduced. Infection occurred prior to

the advent of sulfonamides more commonly than it does now.

Infrequently a fragment of a graft will become infected. When this occurs it must be removed, and once removed the inflammatory process subsides immediately. Rarely does the entire graft have to be removed, though this did occur in 2 of the cases. In each instance this arose in a case in which the plastic repair was conducted too soon after the active osteomyelitic process had supposedly ceased.

In 1 of our cases a tremendous hematoma developed in spite of the routine pressure bandage and drains. The day following the graft, the patient was reanesthetized, the flaps opened up, the graft removed and washed, all clots were removed, minute bleeding points were controlled, and the graft was reinserted. Following this second procedure there was no more reaction than is obtained with the average grafting case, and the ultimate result was excellent (Case 3, Fig. 14).

Cartilage was not used in any of our cases as a primary covering to the dura and has been used only in an occasional case for the creating of cosmetic contour.

To prevent edema of the soft tissues it is imperative to have a pressure bandage applied well over the top of the head. If such a bandage is not used a congestive edema of the scalp will appear in the unbandaged area which reduces the circulation to the grafted area.

Prepared vitallium strips have a curve that would correspond to that of the contour of the average skull and are designed to be used as skull plates. In covering small defects these plates are easy to insert and serve this purpose well. We have employed them as such and have found that if they can be inserted so that their ends are in direct contact with the skull and that their edges conform exactly to the contour of the skull, they will be retained and serve their purpose. This is particularly true when comparatively small defects are encountered, but when the entire frontal bone has been removed, and the shape of the defect is variable and not that of a sphere, it is nearly impossible to bend these strips at the time of operation to meet the above requirements. Because of this difficulty, several of our strips have had an edge slightly above the normal contour. This has eroded through the scalp, due to pressure atrophy and have had to be removed (Case 4, Fig. 15). In 1 of these, it was possible to remove the strip, cut off the area that had presented itself, and reinsert the strip which then remained in place. In 2 instances, it was necessary to remove one or more of the strips. The vitallium plates that are preconstructed obviate this difficulty and have been retained satisfactorily.

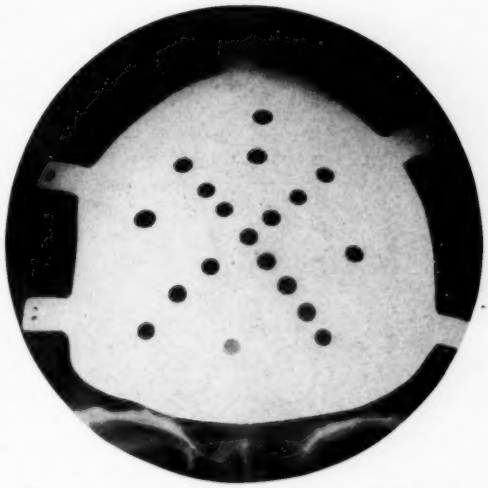

Fig. 11. Case 2. X-ray film of the preformed, perforated vitallium plate in place.

If we desire a thin plate to fill in a defect in the frontal bone, tantalum will probably prove to be the metal of choice for the following reasons: Experimentally it is the most inert of the two main metals at our disposal (5), and it is the more readily formed and altered of the two.

Soon after the insertion of either the strips or the plates, there is apt to be a generalized swelling which apparently occurs adjacent to the metal. Associated with this, there is the customary swelling in the flaps themselves which gradually disappears within 1 to 2 weeks. This early swelling may subside and then reoccur 2 or 3 months later. In 1 case, such swelling occurred about a year later and was due to a collection of fluid adjacent to the plate plus a fibrosis of the tissues over it. On

Fig. 12. Case 3. The presenting disfigurement in a case in which an obliterative frontal sinus, plus removal of one-half of the frontal bone has been carried out. The flap was not sutured into place and has retracted. The defect has covered with epithelium that has invaded from the edges.

3 occasions, it became necessary to aspirate this fluid which was sterile, slightly turbid, and yellow. In other cases, it has subsided without any treatment, and there has been practically no redness or tissue reaction during these episodes. We have found it advisable to have the flat plates perforated so that there may be a free exchange of fluid through from the scalp to the space which is always present between the plate and the dura. Through these perforations, there is also an opportunity for fibroblasts to grow into the space mentioned. This growth may eventually fill and obliterate the area. When the plate is thick so that its inner surface conforms to the shape of the dura and its outer surface to the shape of the finished forehead, this dead space is avoided, but the plate is necessarily heavy if made of vitallium.

In children there is some amount of bone regeneration that does not occur in adults, so that this must be taken into consideration. We have no way of predetermining this regeneration or the amount of anticipated skull enlargement. It seems advisable, therefore, to use a live material such as bone when repairing the defect in children.

We have experienced bone regeneration in 2 of our cases and both of these were in children. There has been no x-ray evidence of regeneration in the adults. This confirms the observation made in skull trephines.

Plates have several practical, as well as theoretical, drawbacks. In the first place we are employing a nonviable material, burying it within the tissues. Theoretically these may be well retained, but practically we must await the test of time before we can evaluate their ultimate success. There have been cases in which gold and ivory have been well tolerated by the tissues for some years, but

Fig. 13. Case 3. X-ray film reveals bony defect of one entire side of the frontal bone including the supraorbital rim and the temporal prolongation.

Fig. 14. Case 3. The end-result following bone transplants; the first from the tibia to cover the entire defect, the second from the ilium to raise the brow. There is still some irregularity of the forehead with slight elevation of the brow.

eventually had to be removed because of sepsis or reaction about it. When we wish to insert a plate it must be prepared to fit the defect as accurately as possible prior to the operation. This is particularly true of vitallium and the acrylic plates which must be precast from a model. It is nearly impossible to alter the shape of a vitallium plate at the time of operation. The only alteration possible is that of the flanges about the periphery. When a flat plate is employed for covering a bony defect, there is left between it and the dura a void space which is a potential source of trouble. This dead space has not caused trouble in our cases other than the accumulation of fluid, but should the fluid become infected, it might be difficult to clear without removing the plate.

To date we have used tantalum and acrylics in but 1 case each. The individual receiving the tantalum was originally operated upon by a surgeon who employed an inverted U incision that was closed early. Following the insertion of the plate there was very little local reaction. This plate was well perforated.

The patient receiving the acrylic plate has but recently been operated upon so that only the immediate reaction can be noted, and that was good. If this material is as well tolerated as we hope it will be, it will probably play an important part in the replacement of lost cranial bone.

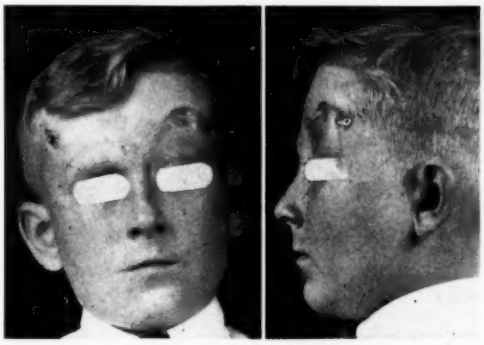

Fig. 15. Case 4. Photograph which illustrates the erosion of a vitallium strip through the brow due to its being elevated slightly above the bone. Note that there is no evidence of infection or inflammatory reaction about the vitallium strip.

Fig. 16. Case 4. X-ray film showing the plates in place having been bent to conform to the skull contour.

SUMMARY AND CONCLUSIONS

The plastic repair of 38 cases of postoperative osteomyelitis of the frontal bone has been reviewed. The indications for operation, the choice of implant material, and the complications encountered have been considered.

Bone, cartilage, vitallium, tantalum, and an acrylic have been employed to replace lost frontal bone. The viable transplants should be employed when practical, as there is no perfect substitute for living tissues. Cartilage may be utilized for replacing small areas of lost bone or for improving the contour of the brow over a previous bone graft. Bone should be used to fill in defects up to 2½ inches in diameter. It is advisable to employ bone in children, as there is some regeneration in these cases as well as a change in skull size. In larger areas it is much easier and the cosmetic result on the whole is more satisfactory when one of the prepared plates is inserted.

If the plates prove to be perfectly tolerated they will in time replace the living transplant as they offer the best protection to the brain, and materially reduce the problems encountered in transplant operations.

Of the plates that may be considered, vitallium and the acrylics must be precast from models, and there is but slight alteration that

Fig. 17.

Fig. 18.

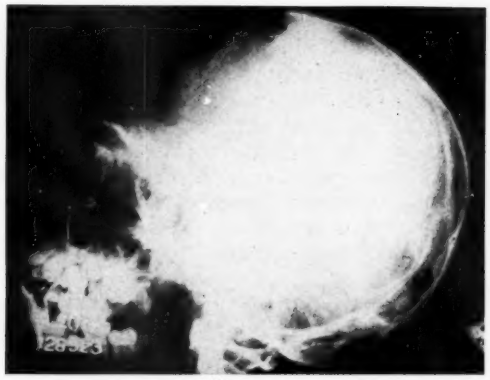

Fig. 19.

Fig. 17. Case 5. Defect in which entire frontal bone is missing. The forehead flaps have retracted and the dura has been covered with epithelium.

Fig. 18. Case 5. End-result following two bone grafts; the first from the front face of the tibia, the second, taken from the crest of the ilium to improve the contour of the brows.

Fig. 19. Case 5. Preoperative defect of frontal bone.

may be made at the operating table. Vitallium must be cast by a special laboratory technique. The model given to the laboratory must therefore be exact. Acrylics may be cast by anyone familiar with the technique and the shape may be altered at operation by heating the plate. Both of these materials have the advantage of creating a plate that can fill in the thickness of the lost bone which it is to replace as well as offering a smooth external contour. A cast in vitallium has the disadvantage of being quite heavy, while one of acrylics is light. A plate of tantalum must also be preformed, but it may be altered by hammering and cutting at the time of operation. It has the disadvantage of leaving a dead space between it and the dura which is a potential source of trouble. We may assume that the bone and cartilage grafts will be tolerated indefinitely as they have previously been well tested. The inert inserts must be subjected to the test of time before judgment may be passed as to their ultimate fate.

Case 1. M. J. F., a 15 year old boy, was operated upon for osteomyelitis of the frontal bone following swimming. The entire frontal bone was removed through an inverted T incision. The flaps and the wound were left wide open. Sulfathiazole was blown into the area, and 3 weeks later the flaps were brought together and sutured in place. Three months later the boy developed a cold. He had pus in his nose, and the wound just above the eyes opened and drained pus. Two months later a left external ethmoidectomy was performed, as this was the site of his recurrent infection. Four months later he was admitted to the plastic service for the insertion of a prepared vitallium plate. He presented a fairly smooth scalp but very flat due to the absence of frontal bone, including the supraorbital rims, and the entire area was pulsating (Fig. 6).

Under general anesthesia, the skin of the forehead was removed from the dura and elevated from the normal bone. The periosteum was incised about the periphery of the defect, was elevated, brought medially, and sutured to the dura. A prepared vitallium plate was inserted and the flanges were bent to conform to the contour of the skull (Fig. 7). Three holes were drilled in the bone, corresponding to three of the holes in these flanges, and vitallium screws were inserted to hold the plate in place. This plate was solid and thick, thus obliterating any dead space. The overlying skin was then reapproximated and sutured with interrupted atraumatic sutures. No drains were inserted. The patient recovered uneventfully, and the result was gratifying (Fig. 8).

Case 2. P. F. M., male, age 20 years, had an operation 1 year prior to admission for subacute osteomyelitis of the frontal bone following swimming. At operation the entire frontal bone was removed, but the supraorbital ridges and floors of both frontals were saved. His convalescence was uneventful.

On admission to the plastic service, he presented the large inverted T-shaped scar on the forehead extending posteriorly to the parietal region of the sagittal suture. The skin flaps were separated and retracted laterally. The region of the frontal bone was flat (Fig. 9).

Operation consisted of "plastic repair of the frontal bone and insertion of a prepared vitallium plate." Convalescence was uneventful though there

Fig. 20. Fig. 21.

Fig. 20. Case 6. Preoperative defect in which the entire frontal bone was removed and part of the cerebrum lost.

Fig. 21. Case 6. Contour following repeated bone grafts utilizing bone from the ilium, plus vitallium strips which were placed on top of these. One of the strips near the supraorbital ridge eroded and had to be removed.

was some postoperative swelling which gradually subsided.

A month later he had a marked swelling of the forehead which was not fluctuant or tender. The tissues were thickened and indurated. This gradually subsided without intervention (Figs. 10 and 11).

Case 3. L. H., aged 25 years, had an acute sinusitis following swimming and developed an orbital abscess. A Lynch frontal and anterior ethmoid operation was done, and the convalescence was uneventful. A month later the swelling of the forehead had not completely subsided and he had a generalized convulsion. At this stage he was admitted to the Massachusetts Eye and Ear Infirmary where it was evident that he had an osteomyelitis of the frontal bone extending out of the left frontal sinus.

At operation, the bone was removed; it was definitely discolored, but no perforation was seen in it. The posterior wall and floor of the frontal sinus were removed and the wound was left open. The organism was Staphylococcus aureus. Four months later the patient was readmitted to the plastic service for a closure of the operative defect (Figs. 12 and 13). Under local infiltration, the skin flaps were dissected from the dura, and the epithelium over the dura was removed. The periosteum was incised 1 inch beyond the margin of the defect and reflected medianward and sutured to the dura. A graft of bone was then taken from the tibia, shaped, and applied to the area of the bony defect. The skin flaps were then brought together and sutured in the midline, and small drains were placed in the incision. A pressure bandage was applied. The following day a huge hematoma had developed and the patient was vomiting. Under local infiltration, the sutures were removed, the flaps laid back with ease, and a huge hematoma was revealed, about 2 centimeters thick, overlying the graft and exposed dura. No

Fig. 22. Case 6. Preoperative bone defect.

bleeding points could be found. The grafts were removed, cleaned of clots, and washed in saline. The wound was cleaned, washed with saline, hydrogen peroxide, and finally 1:1000 adrenalin solution was used to control the general oozing. The bone was then reinserted, the flaps brought together and sutured, and a pressure bandage, utilizing a rubber sponge, was employed. The convalescence following this was uneventful. The end-result from the operation was quite satisfactory, but there remained a depression above the left eyebrow, so that a year following the original plastic operation, a further bone graft was inserted to fill out the contour of this region. This bone was taken from the ilium. X-ray films taken a few months later revealed complete closure of the bony defect, sinuses were clear, and on observation the forehead looked well (Fig. 14).

Case 4. E. J., aged 11 years, 3 months before admission to the plastic service, this young boy had an operation for the removal of osteomyelitis of the frontal bone, an obliteration of the left frontal sinus, and an ethmoidectomy. This operation was done through an inverted T incision. The dura was clean but was covered with sulfanilamide powder, and the flaps were left open. The patient had a very stormy convalescence.

When the patient presented himself to the plastic service, it was observed that the area had healed well, that there was no evidence of infection, but that the customary scarred tissue over the dura was present, plus the corrugations of the flaps. The routine removal of the scarred tissue and freeing of of the flaps was conducted and the bony bed pre-

Fig. 23.

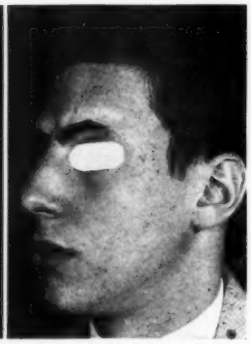

Fig. 24.

Fig. 23. Case 7. Comparatively minor defect in which small area of the frontal bone was removed together with the supraorbital ridge.

Fig. 24. Case 7. End-result following an insertion of a graft taken from the cortex of the tibia.

pared as previously described. Three standard vitallium strips were placed over the frontal bone defect. Each one was bent so as to fit its specific area. This was very difficult to do as it would have been desirable to bend the flat strips in two planes, which was impossible so that at best the plates could not be brought to contact the bone smoothly, and the long edges, though they were smooth, did not conform exactly to the contour of the removed bone. The skin flaps were sutured together and a pressure bandage was applied. Following this operation, convalescence was uneventful, and the immediate result was satisfactory.

Five months later the corner of one of the vitallium strips was presenting through the skin (Fig. 15). This protrusion had apparently occurred by pressure necrosis, as there was no inflammatory reaction about the plates as a whole. This plate was loosened, the protruding corner was cut off, and the strip further bent so that the edge would be pressing against the skull. The skin edges were then reapproximated (Fig. 16).

Six months later the condition of the patient was unchanged, but it was apparent that the long edge of the bottom plate had been gradually approaching the surface, and was visible beneath the epidermis. In view of this process, all the plates were removed and an uneventful convalescence followed.

Two months later the patient had an attack of epilepsy, but a complete neurological examination revealed no evidence of a localized lesion, and the patient was discharged for observation.

When this patient's tissues have had time to reestablish their vascularity, a plate of tantalum will be made and inserted.

Case 5. F. R., male, aged 12 years, had acute osteomyelitis of the frontal bone associated with acute bilateral, frontal and maxillary sinusitis 1 year before admission to the plastic service.

Fig. 25. Case 7. Preoperative defect. Merely the obliteration of the frontal sinus on one side and the removal of a small area of frontal bone.

At operation the frontals were obliterated and the frontal bone removed. One small area of the bone appeared to be diseased and contained pus. There were 3 areas of collected pus on the dura with some granulations around each one. These were about 1 to 2 centimeters in size. There was no further evidence of osteomyelitis according to the x-ray films, and clinically the patient recovered.

The patient presented the usual inverted T scarred area with retraction of the forehead flaps (Figs. 17 and 19). Under general anesthesia, the customary dissection and mobilization of the flaps was performed and the bone prepared to receive the graft. A cortical graft was taken from the tibia, shaped, and placed over the defect, completely covering the dura. The convalescence was uneventful, but in 3 months, further bone grafting was done to improve the contour of the forehead, particularly that of the brows. This time the bone was taken from the iliac crest. Convalescence from this operation was uneventful, and the end-result was unusually gratifying (Fig. 18).

Case 6. W. B., male aged 13 years, had a post-swimming sinusitis, osteomyelitis, extradural abscess, and meningitis 18 months prior to admission to the plastic service. After a stormy course in which all of the frontal bone was removed, he presented himself with the flaps retracted, the dura covered with epithelium, and a very flat forehead (Figs. 20 and 22). At operation the retracted flaps were freed, the dura cleaned of epithelium, and the flaps approximated and sutured. The appearance of the forehead at this period was markedly concave. Six months later bone was taken from the ilium, shaped, and inserted beneath the flaps. It was impossible to cover the entire forehead due to the tremendous area involved. The convalescence from this was un-

eventful. Four months later he developed marked pain and swelling over the glabella region. There was no history of recent infection or cold. An abscess developed which was incised and drained. It subsided without further trouble. Six months later he still had a small draining fistula at the roof of the nose. X-ray films showed no evidence of infection, and that three-fourths of the bony defect had been filled in by bone. Eighteen months following the first bone graft, further transplantation was done, and bone was taken from the iliac crest, in the form of strips that were fitted into the defect, and held in place by the closed scalp. This improved the contour and shape of the forehead considerably, but there was still much depression above the hairline, and there was still marked depression in the region of the brows. Four months elapsed when the flaps were again elevated, and a small standard vitallium strip was placed over the brow just over the roof of the bone, and sewed in place. Two more vitallium strips were placed above the first one and sewed in place, the skin approximated, and a pressure bandage applied. One month later the ends of the vitallium strip that were near the brow had eroded through the skin and had to be removed (Fig. 21).

CASE 7. W. E., aged 18 years, was operated upon for osteomyelitis of the frontal bone associated with a brain abscess 11 years ago. Since that time, there have been no complicating symptoms. Examination showed a vertical L-shaped scar, extending from the center of the forehead to the eyebrow. It was wide and adherent to the bone. The skin within the area of the L was puckered and elevated (Fig. 23). Palpation showed absence of bone beneath the area. The eyebrow was distorted. X-ray pictures of the skull and sinuses showed no evidence of infection, but a bony defect measuring 2 by 3 centimeters in size (Fig. 25).

At operation the scar was excised and the flap dissected away from the dura to existing bone. The scar tissue over the frontal defect was thin, and in one area, a small cyst was encountered. The forehead was prepared for the reception of a bone graft and a rectangular piece of bone, 2 inches long and 1 inch wide, was removed from the cortex of the tibia, shaped, and inserted over the dura with its periosteal side outermost. The skin flaps were then closed over the bone graft and a pressure dressing applied. The patient made an uneventful convalescence (Fig. 24).

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ALPHA RAYS IN THE TREATMENT OF WOUNDS

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THE therapeutic potentialities of radium and radioactive substances are not utilized to their fullest extent. Some of the principal reasons for the conservative attitude toward their use are the relative rarity of the element, the inconveniences connected with the handling of radioactive substances, and the fact that many physicians are not familiar with the technical application of radium and its disintegration products. The use, therefore, of radioactive substances in medicine is generally limited to the treatment of malignant tumors. This important employment of radium, however, does not exhaust its therapeutic usefulness, and developments in the past two decades have shown that other diseases may be treated successfully with radioactive substances. Furthermore, technical progress has made radium products more readily available, and in such form that they can be safely used by every physician.

In order to avoid loss of the valuable element, and for economic reasons, radium itself is often substituted by radium emanation, also called radon, a disintegration product of radium in gaseous form. This substance has the same qualities as radium, but can be, and has been, used in forms in which radium itself cannot be prepared. A distinct feature is the fact that radon is readily absorbed in fluids such as water or alcohol, and is easily incorporated in fatty substances. This property not only facilitates its therapeutic application but also permits utilization of the alpha rays emanated by radon. It will be shown that α-radiation is of great therapeutic value in wound healing, and the probability that war wounds may be benefited by its application prompts this publication.

Little use has been made of α-rays in medicine and only a minority of physicians is generally aware of the fact that over 90 per cent of all the emanation from radium and radon consists of alpha particles, the rest being β- and γ-rays. The pathway of α-rays is very limited, amounting to only a few centimeters in air of normal density, and their penetrating power is so slight that the walls of the containers ordinarily used for radioactive substances absorb all the α-rays given off. These qualities nullify the usefulness of α-rays for the treatment of malignant tumors, in which, except for lesions on the surface of the skin, the penetrating γ-rays have the chief therapeutic value. However, when radon is incorporated in fluids or fats, these substances can easily be brought into close contact with lesions on the surface of the body and full advantage can be taken of the α-rays.

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As long as twenty years ago, Strasburger (1) introduced radon in a liquid vehicle into therapy. For the past 15 years (2), radon dissolved in fat substances has been successfully used for the treatment of skin changes and ulcerations which resulted from overdosage of x-rays and radium. These ulcerations are characterized by the pain associated with their appearance, their resistance to therapy, and by their eventual development into cancer with all its consequences. It is well known that many of the pioneers in radiology, being in their time utterly unaware of the dangers of overexposure, succumbed to x-ray cancer.

It may seem odd and inconsistent to attempt the cure of injuries produced by x-rays or radium with the same agent, but it must be emphasized that the recommended therapeutic factor for these skin changes consists of α-rays which are corpuscular elements and physically different from γ-rays of radium or x-rays. In the dosage employed for these treatments, α-rays have been proved to be absolutely harmless in many thousands of applications.

Radon incorporated in neutral fat is a source of α-rays and has the appearance of an ointment. It can be handled like other salves but consideration must be given to the fact that it is not a stable product. Radon disintegrates and loses its strength by continuously giving up part of its charge. This loss has been exactly determined and amounts to about 16 per cent in every 24 hours. An ointment with a known amount of radon will lose half of its concentration in about 4 days. This quality necessitates the preparation of fresh material for therapeutic applications, and the exact determination of its concentration in order to evaluate the time element for its use.

The construction of suitable apparatus and measuring instruments has made the task of preparing radon ointment and determining the exact dosage comparatively simple, and the material has been made available to the medical profession for general use. The actual amount employed for

the therapeutic purposes described here is exceedingly small. Radon in this form is measured in electrostatic units (e.s.u.), 1 electrostatic unit being equal to 0.000364 millicurie destroyed (m.c.d.). Since familiarity with these physical standards cannot be generally assumed, it may suffice to mention that 10 cubic centimeters of radon ointment containing a total of 1000 electrostatic units (100 e.s.u. per c.c.) can be applied continuously for more than 100 hours before an erythematous reaction of the skin will be produced.

Another factor important for the therapeutic use of radon ointment must be mentioned. Radon, as previously stated, is a gas and has the tendency to escape. To prevent this, the ointment is prepared and shipped in sealed tubes or in tin containers, and when used for therapeutic purposes, should be applied under dressings as airtight as possible. In the treatment of surface wounds, this can be easily accomplished by spreading the ointment over the lesion, covering the area with rubber dam, cellophane, oilcloth, or similar material, and finally sealing the dressing with adhesive tape in overlapping strips. These dressings must be applied by the physician and are left in place for an exact and predetermined time. They then can be removed by the patient. Repetition of the treatment is usually done at intervals of 3 to 7 days. The treatment time depends upon the nature of the lesion, and the number of treatments required is influenced by its size.

The use of radon ointment was originally limited by the author to the treatment of wounds which had proved to be resistant to all other forms of therapy, and in cases in which wide excision of tissue with subsequent grafting of skin or even amputation of limbs was contemplated. Most of these lesions were sequelae of overdosage

Fig. 1. Case 1. a, left, Before and, b, after 5 weeks of radon ointment treatment.

of x-rays or radium. The results obtained were extremely gratifying. Consequently, when radon in this form became more easily obtainable, other skin conditions with similar resistance to ordinary therapy were subjected to these treatments. Periodic histological studies of such lesions showed that new capillaries were formed under radon ointment therapy. Therefore, these treatments were instituted in ulcerations of the skin where the local blood supply was incompetent. In this manner patients suffering from Buerger's disease, varicose ulcers, necrotic lesions including diabetic gangrene, resistant burns resulting from heat or electric current, and draining fistulas were successfully treated.

During the past year the influence of α-rays on experimental surgical wounds in rabbits' skin was

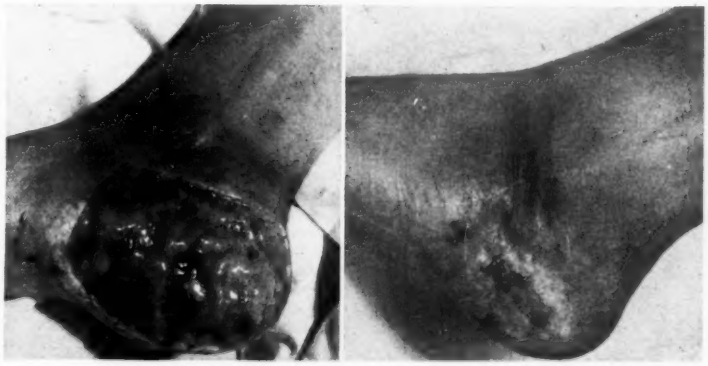

Fig. 2. Case 2. a, left, Before and, b, 6 months after radon ointment therapy.

Fig. 3. Case 3. a, left, One week after removal of carcinoma of hand and 2 days after radon ointment therapy; b, 3½ weeks later after 6 treatments.

studied and valuable information on the subject of wound healing and scar formation obtained. These wounds, to be reported in a separate communication, did not always correspond to changes in human tissue, but in the response to radon ointment therapy a surprising similarity in rabbits' and human skin was observed. Uniformly, the healing process of extensive wounds was accelerated by the application of radon ointment.

Fig. 4. Case 4. a, left, After removal of epithelioma, and, b, after 4 treatments with radon ointment.

Clinical results obtained in surgical wounds selected on the basis of experience gained in the experimental work, confirmed the value of radon ointment applications. The rate of wound healing was greatly hastened, and surprisingly soft scars were produced without impairment of function. Some of these histories are briefly presented:

CASE 1. H. S. Carcinoma of the skin below the left eye was treated with radium in 1937 and 1938. Dosage unknown. In 1940, an excision of the lesion was performed but the lesion recurred, and another operation was carried out in 1941. There was granulation tissue in the wound, and on several occasions biopsy specimens were taken from this tissue, which in some instances showed remnants of carcinoma. Eventually the wound became clean and in March, 1943, appeared as illustrated in Figure 1 a. The tissue defect measured about 3.5 centimeters by 1.5 centimeters, and was 1 centimeter deep. The periosteum was exposed and while there was no clinical evidence of carcinoma, the possibility of a necrosis of the bone was considered. Biopsy specimens taken from the margin of the lesion at that time did not show any microscopic evidence of carcinoma. Skin grafting was contemplated to cure the lesion. Before that was done, treatments with radon ointment were begun on April 15, 1943. After 2 applications, new granulation tissue was formed along the edges and over the base of the lesion, and under continuous treatment the defect filled in. After 5 weeks the lesion presented the picture as shown in Figure 1b, but applications of radon ointment were continued until July 15 without much change in the appearance of the scar. A total of 19 treatments, each lasting over 8 hours, was applied, and the lesion has remained unchanged in a follow-up period over 6 months. The scar is soft and shows no tenderness. After

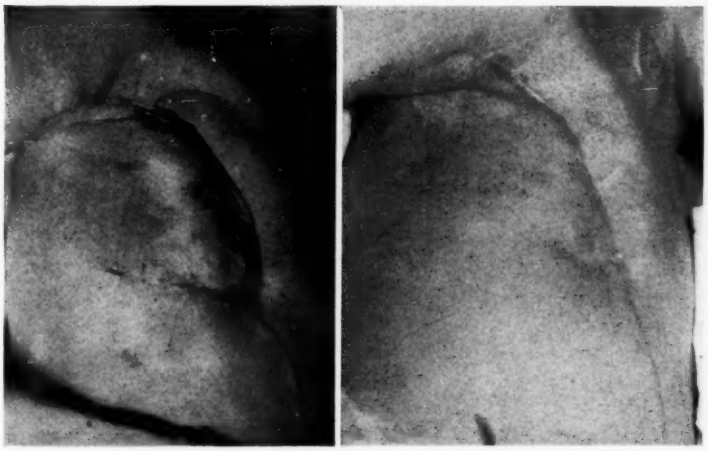

Fig. 5. a, left, Wound after radical mastectomy. b, Therapeutic result after radon ointment treatment.

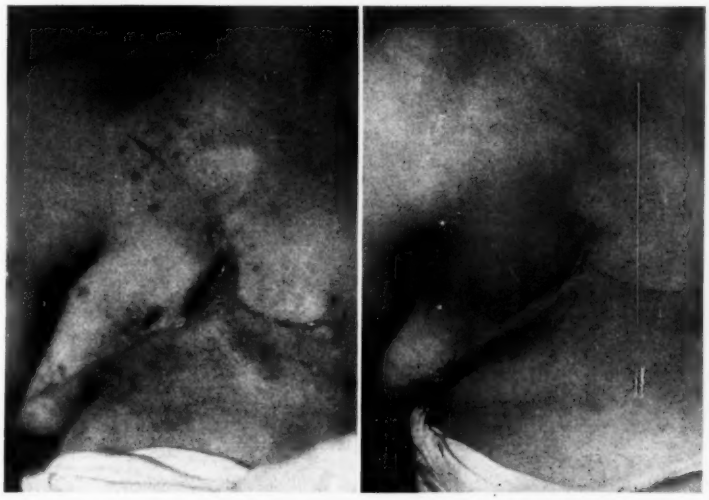

Fig. 6. a, left, Similar lesion to that in Figure 5; b, after treatment.

this paper was submitted for publication, the patient developed an erosion the size of a small pea in the medial part of the scar with indurated and hyperkeratotic borders. Recurrence of the original carcinoma was suspected and biopsy advised.

CASE 2. E.Y. had an eczema of the left lower extremities and received more than 30 x-ray treatments in 1937. Following these treatments she developed severe reactions over the left heel and ankle which resulted in an ulceration of the skin which failed to heal. She was under constant medical care with all types of treatments including cautery, and during the year 1942 developed hard indurated areas in the borders of the ulcer. The patient was first seen in the department on February 1, 1943, with the lesion as described, and biopsy tissue was taken from the margin of the ulcer. The section showed a squamous cell hyperplasia, suspicious of carcinoma. On February 9, she was operated upon, and the entire ulcerated area was removed. The surrounding tissue showed atrophic changes with telangiectases. The defect resulting from the operation measured 10 by 5 centimeters, and had the appearance as in the Figure 2a. Radon ointment therapy was started on February 15 for an 8 hour period and repeated on February 18. Following these 2 treatments there was so much improvement with

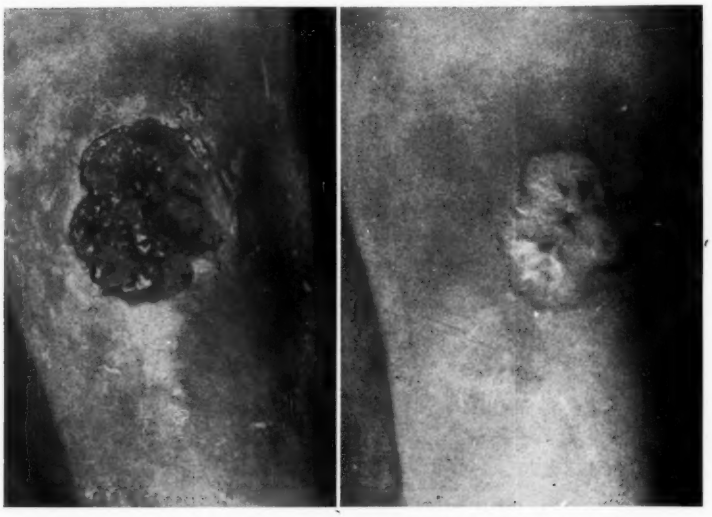

Fig. 7. Case 7. a, left, Ulcer of leg before, and, b, after radon ointment therapy.

formation of granulation tissue that the patient could be discharged from the hospital and returned to Alabama for continued radon ointment therapy as an ambulant patient of her local physician. Subsequently, 13 more radon treatments were given in the ensuing 3 months, and the patient returned for a follow-up examination on August 31, 1943. The photograph taken at this time showed the appearance of the heel as in Figure 2b. Four more treatments with radon ointment were applied between August 31, and September 9, with further improvement of the scar.

Case 3. Dr. H. L. The patient is a physician who had exposed his hands to x-rays over a period of 30 years with the production of severe atrophy, telangiectases, and hyperkeratoses on both hands. In 1940, a small tumor on the dorsum of the right hand started and grew into a mass measuring 4 by 5 centimeters protruding 1.5 centimeters above the level of the skin. This was a typical x-ray carcinoma, the surrounding parts of the skin showing typical x-ray changes.

On September 17, 1942, the carcinoma was removed surgically down to the tendon sheaths, and radon ointment therapy was started on September 22. Figure 3a taken on September 24, 1 week after operation, already showed granulation tissue on the bottom of the lesion, and under continued therapy, the lesion healed within 3½ weeks with a total of only 6 radon ointment applications. The resulting scar is unusually soft and does not in any way limit the movements of the hand. Figure 3b taken at a follow-up examination at a later date, shows the therapeutic result. The patient was last seen in November, 1943, and there was no change in the appearance of the hand.

Case 4. D. G. The patient had an epithelioma on the left side of the nose for several years and received radium treatments some years ago. He was first seen in the department on July 26, 1943, and showed swelling of the left cheek and the left side of the nose with deep ulcerations and some areas of hypertrophic tissue. It was thought at that time that the patient had a radiation injury and a carcinoma, and following some treatments with radon ointment, most of the ulceration healed except for the central part which measured about 2.5 by 2 centimeters, and showed hard and elevated borders. This lesion had the typical appearance of a carcinoma, and the entire area was removed surgically on September 23 (Fig. 4a). Microscopic examination of the specimen confirmed the diagnosis. Treatments with radon ointment were started on September 27, and continued for 2½ weeks. Granulation tissue began to form immediately after the first application, and after four treatments (the last one given on October 14) the lesion was completely healed as in Figure 4b.

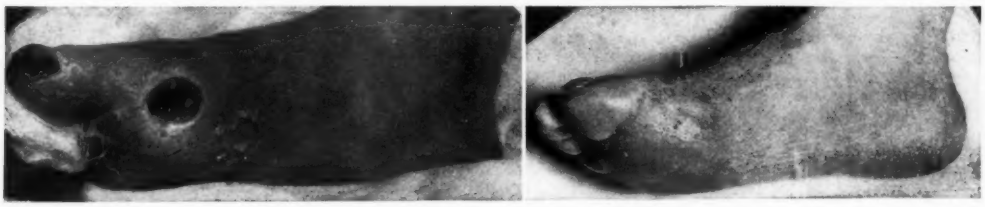

Fig. 8. Case 8. a, left, Before and, b, after the administration of radon ointment treatment of arteriosclerotic ulcers on the toe of the right foot and over the right metatarsal joint.

These 4 cases are presented to show the effect of radon ointment therapy on the healing of surgical wounds. In all cases, operations were performed for the elimination of carcinomas in an area previously injured by radiation. It is well known that under these circumstances the wound healing is not very satisfactory due to the lack of circulation and atrophy in the surrounding tissue. We have frequently observed patients with similar lesions in which, following the surgical removal of the neoplasm, skin grafts were carried out and failed to take. In the cases just mentioned, the surgeon who performed the operations was very skeptical about the outcome, and based this skepticism on his experience in similar instances. But all these patients could be discharged from the hospital within 1 or 2 days except in Case 2 in which, for reasons of convenience, the patient stayed 9 days in the hospital before the treatment was continued ambulatorily. The rate of wound healing was unusually fast and the resulting scars impressed us with their soft, smooth, nonadhering appearance.

In connection with this description, mention should be made of similar experiences with radon ointment therapy in a related field. Following extensive operations, as for example, radical mastectomy in cancer of the breast, the wound healing is often slow, and sometimes requires many weeks or even months before drainage from the scars stops, and complete healing takes place.

Figure 5a shows a wound following a radical mastectomy in a patient who had a local breast operation several months before the radical mastectomy was performed. The mastectomy, therefore, was done under a handicap on April 17, 1943, and on May 29, the wound showed the appearance as illustrated. There was no progress in wound healing for the ensuing 3 weeks, and the patient complained about severe pain and drainage. The actual wound measured about 10 centimeters with an average width of 2 centimeters and a depth of 1 centimeter. Radon ointment therapy was started on May 29, and continued until June 21, 5 treatments being given. Following the second application, the wound was less than one-half its original size and was completely healed by the end of June, 1943. Figure 5b shows the therapeutic result following the application of radon ointment.

Figure 6a shows a similar pathologic lesion in which a radical mastectomy for carcinoma of the breast was performed on June 15, 1943. The center of the wound did not show any tendency of healing, and presented a necrotic ulceration measuring 3.5 by 2 centimeters. Radon ointment therapy was started on July 19, and 6 more applications were given to the area. Figure 6b shows the appearance of the lesion on September 2, 1943, again indicating the soft, nonadhering scar following radon ointment therapy.

These are only 2 examples of a number of patients with nonhealing operative scars following various types of operations. In some instances, there was drainage of wounds from abdominal operations from 6 to 9 months, and 3 or 4 applications of radon ointment were sufficient to produce a soft scar and the cessation of drainage.

The following description is an example of a lesion in which no surgical excision was carried out but in which other surgical procedures were unsuccessful.

CASE 7. H. G. The patient had a varicose ulcer on the left lower leg for over 4 years. Many types of therapy were carried out during this time without appreciable improvement. Within the past year, skin grafts were performed by various competent surgeons on three different occasions, but these did not take, and the patient was eventually referred for radon ointment therapy. Figure 7a shows the large ulcer measuring over 4 centimeters in diameter on the left lower leg, and according to the patient, there had been no change in the appearance of the lesion for the past 6 months. Radon ointment therapy was started on October 14, 1943, and 3 weeks later the lesion was about one-half its original size. Treatment was continued until November 29, 1943, and Figure 7b shows the result obtained within this time.

Finally, successful therapy with radon ointment is reported in a case in which radical surgical procedure could be avoided, the patient suffering from diabetes for many years.

CASE 8. M. R. When first seen in November, 1939, the patient had been in the hospital for the treatment of two arteriosclerotic ulcers on the toe of the right foot and over the right metatarsal joint. After 3 months of conservative treatment, the lesion showed the appearance as illustrated in Figure 8a, and since no further improvement could be achieved, amputation of the leg was contemplated. There was faint pulsation in the anterior and posterior tibial arteries. Radon ointment therapy was started on November 1, and continued for 6 weeks until December 13, 8 treatments of 8 hours each being given altogether. Following these treatments, the lesions were completely healed and showed the appearance as illustrated in Figure 8b. The patient has remained under our control, and the ulcers have remained cured now for over 4 years.

The photographs of the patient last mentioned taken before and after radon ointment therapy show better than any lengthy description the results obtained with this new form of therapy. However, they do not fully demonstrate the type of scars which were obtained in healing these lesions. These were surprisingly soft and appeared to be epithelium rather than scar tissue. Surgical wounds in areas of impaired nutrition without spontaneous tendency of healing or operative wounds which failed to heal for several weeks or months were greatly benefited by radon ointment applications as were several varicose ulcers of long standing and diabetic gangrene which had been treated unsuccessfully by other methods. In some instances, skin grafts had been performed at a previous date without beneficial results (Case 7), and in others, as in Cases 2 and 3, skin grafting had

been contemplated and was not carried out because the prompt response to α-ray therapy made this procedure unnecessary. In other instances not mentioned here, similar results could be obtained in skin burns of second and third degree resulting from heat and electric current.

SUMMARY

The use of α-rays in the treatment of wounds has been very successful. Some of their values lie in the fact that:

1. They can be used in ulcerations in which the local blood supply is impaired and which do not respond to other forms of therapy.

2. The treatments can be carried out easily by every physician who has familiarized himself with the method and the patient can usually be cared for in an ambulatory manner.

3. The wound healing process is greatly accelerated.

4. The resulting scars are extremely soft, smooth, nonadherent, and do not impair the function of limbs even if present at joints.

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A NEW SIMPLIFIED METHOD OF DEFUNCTIONALIZING THE COLON

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THE progress of large bowel surgery has been retarded for many years because of the omnipresence of pathogenic organisms residing there. Reconstructive procedures on the colon and rectum have been attended by a high morbidity and mortality.

There are two dominant reasons why the pathogenicity of organisms in the colon influence the ultimate result of operative procedures on this portion of the gastrointestinal tract. First, in an open procedure, when a portion of the colon is resected and an anastomosis done, there is usually some contamination of the operative field from the contents of the bowel, regardless of the meticulous care of the operator. If the peritoneum cannot resist the invasion of these organisms, there is a predisposition to postoperative peritonitis, intra-abdominal abscess, fecal fistulas, or wound infection. Second, even in the so called aseptic anastomoses, when colonic organisms are present in high concentration, the suture lines do not heal under ideal conditions, and leakage may occur.

For the past few decades, surgeons have tried to render the colon relatively aseptic by various means. The different cathartics were tried with poor results. Enemas of the various antiseptic solutions and solutions of low surface tension were proved ineffective. Enemas and instillations of drugs were tried by way of colostomy, to no avail. In the latter method, when a simple cecostomy or loop colostomy was performed, the cleansing of the distal colon was impossible because of the overflow of septic feces from a point proximal to the artificial opening in the bowel to that distal.

In 1938, Sir Hugh Devine overcame this obstacle in his published report on the defunctionalized colon. According to Devine, "A defunctionalized colon is one which has been completely disconnected from the alimentary canal so that it cannot be soiled in any way by even the smallest quantity of the feces; one from which the fecal contents have been washed out and one which has been allowed to remain functionless until such time as the bacterial content has been considerably reduced; reduced on the principle that if, experimentally, a segment of bowel be completely isolated and thus deprived of its function, it will lose most of its bacterial content." Devine points out "The two important points in this method of operating on the defunctionalized colon are, first, that the operation is carried out under favorable conditions, that is, absence of septic feces, functionless, contracted colonic walls and low bacterial count; and, second, that the wound in the intestine is allowed to heal under these conditions."

Devine defunctionalized the distal colon in a two stage procedure. A loop of bowel (which must be a mobile loop, usually a portion of the transverse colon) is brought up, clamped, and bisected with the cautery, and a spur is formed by uniting the two segments of colon by suture. Two small incisions are made in the skin on either side of the initial incision, the ends of the bowel are then brought up under the skin and onto the abdomen through the two incisions previously mentioned; thus the proximal and distal portions of the colon are separated by an expanse of skin preventing the spillage of feces from the proximal into the distal segment. In the next stage, after the lesion has been excised from the distal loop, the spur must be crushed and in the final stage, the stumps of bowel must be turned in and the wound closed.

There are many faults with the Devine colostomy. It can be performed only on a mobile loop of colon with any facility, usually the transverse colon and is obviously inadequate for operative procedures in this portion of bowel or proximal to it. It is a two stage procedure which necessitates more than one anesthetic with its concomitant dangers. It is a fairly lengthy first stage operation, in view of the fact that it is only an adjuvant to the main procedure. There is more than one skin incision which is undermined when the loops of bowel are brought out, with an increased chance of infection. There is also the factor that the bisection of the bowel when the loops are being formed introduces the possibility of contaminating the peritoneal cavity in the first stage.

In the new simplified method of defunctionalization to be described, all of Devine's pre-

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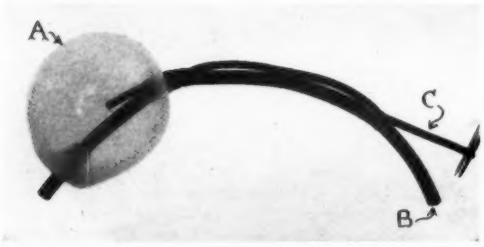

Fig. 1. Original tube. *A*, Inflated balloon; *B*, proximal opening of main lumen; *C*, tube for balloon inflation.

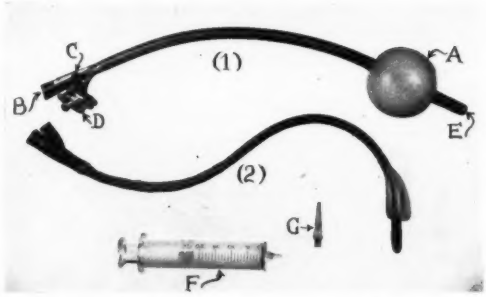

Fig. 2. Bardex No. 30 barium enema tube for ascending and transverse colon. *A*, Inflated balloon (100 cubic centimeter capacity); *B*, proximal opening of main lumen; *C*, opening for balloon inflation; *D*, Hoffman clamp; *E*, distal opening of main lumen; *F*, 20 cubic centimeter syringe (for accurate measurement of inflation); *G*, adapter between syringe tip and tube of inflation; *2*, similar tube with balloon of 50 cubic centimeter capacity for sigmoid colon.

requisites are met, without completely disconnecting the alimentary canal. It may be used to decontaminate any part of the large bowel distal to the first portion of the ascending colon. It is simple and entails only the use of a temporary cecostomy or loop colostomy. These procedures are done routinely preliminary to large bowel resection, especially in the presence of obstruction.

The procedure is as follows: A temporary cecostomy or colostomy is done. After 4 or 5 days, when the bowel is firmly peritonealized, a special tube is inserted distally through the opening in the colon. This tube is essentially a double lumened enema tube with an inflatable balloon attached (in the manner of a Miller-Abbott tube, Fig. 1). The main lumen is through and through with a diameter of three-eighths of an inch. The smaller lumen is the means by which the balloon is inflated. At first, this home-made tube was used, but due to certain difficulties which will be described later, a Bardex barium enema tube was found much more suitable (Fig. 2, *1*). The tube is greased and inserted into the colostomy proximal to the lesion. The balloon is inflated with the amount of air necessary to fill and distend this portion of colon (Fig. 3). Thus, the balloon obstructs the passage of contaminated feces from the portion of the bowel proximal to the balloon to that distal. The feces exist through the line of least resistance, the colostomy opening (Fig. 3, insert). The main lumen of the tube, however, is open and connects with the outside the segment of bowel to be defunctionalized. Cleansing instillations may be administered through this lumen and siphoned off, thus decontaminating the segment of bowel with the lesion. In this manner, any portion of the colon distal to the first portion of the ascending colon can be readily defunctionalized. The only complications would be those inherent in the simple colostomy.

Relative to its surgical use, this method of defunctionalization is especially adapted to open resections. There would be a rather aseptic and clear operative field. After operation, whether an open or an aseptic procedure is done, there would be no tension on the suture lines and no contaminated feces flowing over it, thus predisposing to quicker healing. The anastamosed portion of the bowel would be collapsed and at rest which is ideal. In certain inflammatory conditions of the colon or rectum, whether it be primary, as diverticulitis, or secondary to a malignant growth, this method of defunctionalization would materially aid its subsidence. It would obviate even the occasional use of the Miller-Abbott tube (4), after operation, in large bowel surgery.

CLINICAL EXPERIMENTS

There were many problems to be solved in the practical application of this theory.

The type of balloon to be used, relative to its size, shape, thickness, and durability.

The size of the balloon would necessarily have to be large enough to distend and occlude various portions of the colon. At fresh postmortem, a balloon was placed into the ascending, transverse, and sigmoid colons and inflated. It was found that the amount of air necessary to fill each major portion of colon was dependent on the diameter of the different portions of colon and on the elasticity of the balloon. On using the tube finally selected (Bardex barium enema tube, (Fig. 2, *1*)), the ascending and transverse colon distended on inflating with air to 100 cubic centimeters; the sigmoid with 50 cubic centimeters of air. The tube was then tried on 2 patients, one with a cecostomy and one with a loop sigmoidoscopy. It

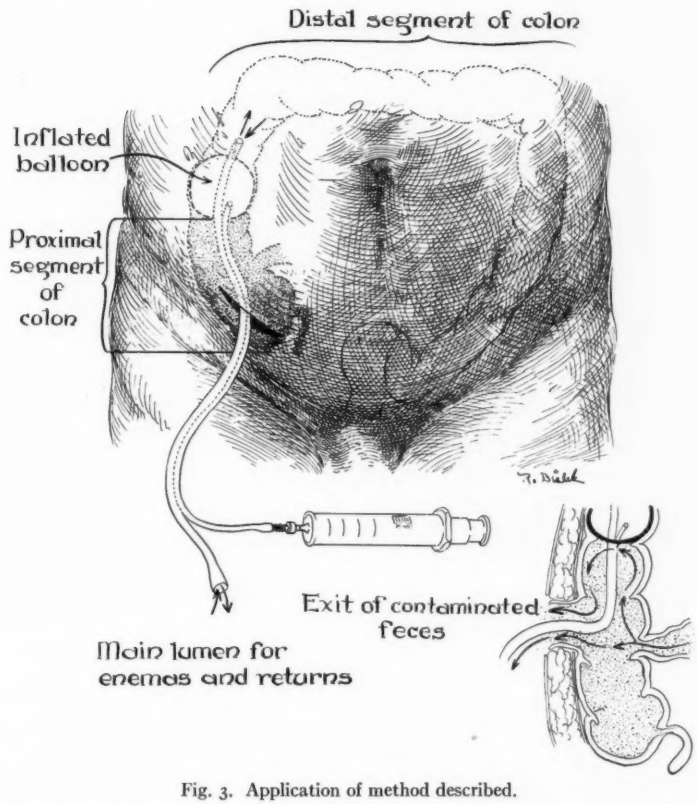
Distal segment of colon
Inflated balloon
Proximal segment of colon
Exit of contaminated feces
Main lumen for enemas and returns

Fig. 3. Application of method described.

was inserted into the respective portion of the colon and the balloon inflated until peristalsis was palpable in the inflating syringe. Under fluoroscopy, thin barium was injected around the tube and into the opening in the portion of colon previously mentioned. The balloon was gradually inflated until it obstructed the passage of barium under fluoroscopy. The amount of inflation necessary for obstruction was 90 cubic centimeters in the ascending colon and 40 cubic centimeters of air in the sigmoid.

The ideal shape for the balloon, if it is to obstruct the passage of feces, would be cylindrical. This would give the broadest possible surface contact with the least chance of spillage during a peristaltic wave. The cylindrical balloon has not been constructed, as yet.

The rubber from which the balloon is made should be thick enough to withstand a pressure of inflation up to the point where it distends the bowel, plus the increased pressure of colonic contractions. It should also be flexible enough, however, so that it would conform to the shape of the colon without traumatizing the mucous membrane. The texture of the rubber must be durable and able to withstand the mechanical and chemical contact of intestinal secretions and feces.

A Miller-Abbott balloon attached to a rubber tubing was first used (Fig. 1) through a cecostomy. It could be distended to the correct size and its shape conformed readily to the bowel. However, it was somewhat light in weight and some barium given by mouth was found to have passed around its margin and into the distal segment of the bowel, by x-ray, in 1 case. There was not enough pressure exerted by this thin balloon to obstruct the bowel consistently. On keeping this type of balloon distended in the bowel for several days, it was found, on 3 occasions, to have ruptured and deflated. A heavier latex condom was then used, in which a greater pressure was able to be exerted. The results were more favorable, but not wholly

Fig. 4. X-ray film of tube and inflated balloon in hepatic flexure of colon through a cecostomy. Fifteen hour film after taking barium orally. *A*, Inflated balloon; *B*, obstructed barium in proximal segment of colon. No barium flows past the balloon.

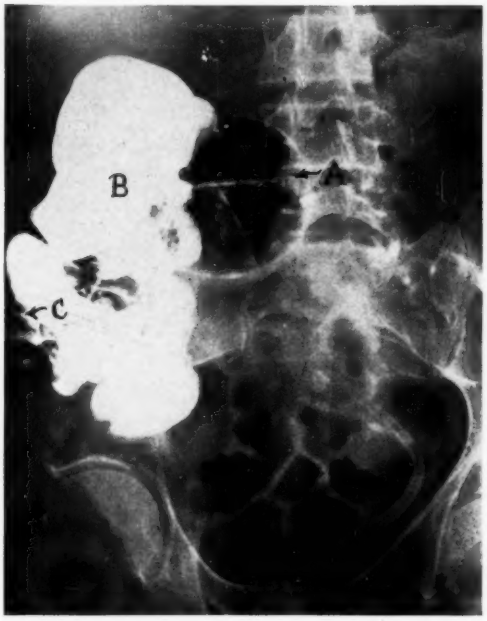

Fig. 5. Same as in Figure 3, 39 hours after per oral barium. *A*, Inflated balloon; *B*, barium in obstructed cecum and ascending colon—still no leak into the distal segment of colon; *C*, some barium passing through cecostomy around the tube. This cecostomy was tight around the tube. Emptying complete with dilatation.

reliable. It was then decided upon to use a No. 30 Bardex barium enema tube with balloon attached. The rubber in the balloon portion is much thicker but it is less distensible and does not conform to the shape of the colon as well. It also exerts a much greater pressure on the bowel wall. This tube was tried through a cecostomy distending the balloon with increasing amounts of air, under fluoroscopy, until it obstructed the flow of barium injected into the proximal segment of colon around the tube. It obstructed when the balloon was filled with 90 cubic centimeters of air. A barium meal was then given the patient and x-ray films taken at 15, 24, and 39 hours. All of the barium was seen roentgenologically to come out through the cecostomy around the tube and onto the abdomen. No barium was seen to go beyond the balloon (Figs. 4 and 5). Some barium was then forced through the cecostomy, lateral to the tube, under pressure. None leaked beyond the balloon (Fig. 6). About 250 cubic centimeters of light barium was then instilled through the main lumen of the tube into the segment of bowel distal to the balloon. There was no back leakage and the balloon was found to be able to withstand the weight of a column of barium (Fig. 7).

These same experiments were repeated on a loop sigmoidoscopy. In this portion of bowel, a tube with a 40 cubic centimeter capacity of the same design as the Bardex tube was used (Fig. 2, *2*). All of the experiments, by x-ray, showed that this balloon effectively obstructed the sigmoid (Figs. 8 and 9).

This was definite enough evidence that no feces under normal pressure would pass from that portion of bowel proximal to the balloon to that distal.

The question of impairment of circulation by pressure of the distended balloon on the vessels supplying this segment of colon was considered. It is a known fact that distention of bowel does exert some influence on its circulation. In 1907, Van Zwalenburg made certain observations on the intestinal blood flow during distention. He found, experimentally, that the current of flow was slowed in the veins at 90 millimeters of mercury. At 130 millimeters of mercury, all circulation ceased. Dragstedt corroborated these findings and on further investigation found that the circulation, both arterial and venous, is more vul-

Fig. 6. Original tube and balloon through cecostomy. X-ray 7 hours after per oral barium. More barium injected around the tube into the cecum under pressure. Balloon still obstructs flow of barium. *A*, Inflated balloon in ascending colon; *B*, barium injected into proximal segment of colon obstructed; *C*, barium in terminal ileum.

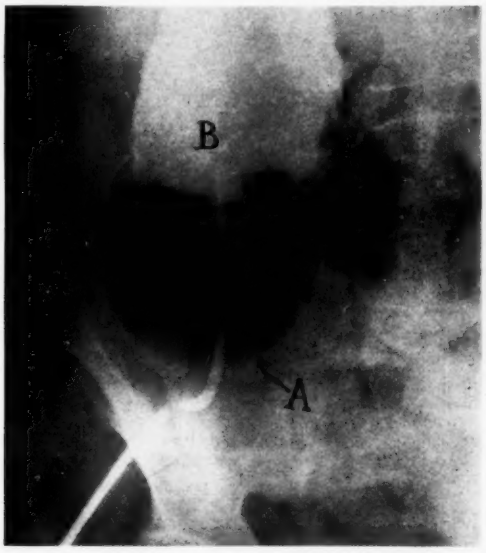

Fig. 7. Tube with balloon in proximal portion of ascending colon through cecostomy. Barium injected through main lumen of tube into distal segment of colon. X-ray film 45 minutes after injection in upright position. *A*, Inflated balloon in ascending colon; *B*, barium in distal segment of colon. No leak back of barium around the balloon.

nerable to the effects of distention in the duodenum and becomes progressively less so as the rectum is approached. It takes a much higher pressure to occlude the blood supply of the colon than the small intestine. He also observed that prolonged distention gradually increased the flow of blood through the anastomotic vessels until it nearly equaled the original flow.

The large Bardex barium enema balloon, when inflated with 90 cubic centimeters of air, exerts approximately 105 to 110 millimeters of mercury pressure. It was doubtful whether this balloon could be kept inflated at this pressure for any length of time without disturbing the blood supply of the colon.

In the first case in which the Bardex tube was tried (an inoperable carcinoma of the splenic flexure) it was placed through a cecostomy and into the ascending colon. The balloon was inflated with 40 cubic centimeters of air. The following day, an additional 10 cubic centimeters of air was injected and after 6 hours, 10 cubic centimeters was withdrawn. The next day, 20 cubic centimeters of air was injected and only 10 cubic centimeters removed, after 6 hours. A daily increment of 10 cubic centimeters of air was injected in this manner until 100 cubic centimeters of air were safely in the balloon with no obvious subjective effect on the patient. The air was allowed to remain in for 9 days. The patient had no complaints during this period and there was no clinical evidence, abdominally, of impairment of blood supply to the distended portion of the colon. It was, therefore, assumed that the balloon distended with 90 cubic centimeters of air was safe at a pressure of 105 to 110 millimeters of mercury and had no damaging effect on the circulation to the bowel. The same procedure, using 40 cubic centimeters of air was done through a sigmoidostomy.

The problem of mucosal necrosis occurring due to the pressure and friction of the rather stiff rubber balloon on the bowel was also considered. This was proved not to be the case in the following manner. The tube was inserted into the sigmoid colon through a sigmoidoscopy opening on the anterior abdominal wall of a patient who had had a preliminary cecostomy and subsequently an abdominoperineal resection. The balloon was placed about 4 centimeters below the skin margin

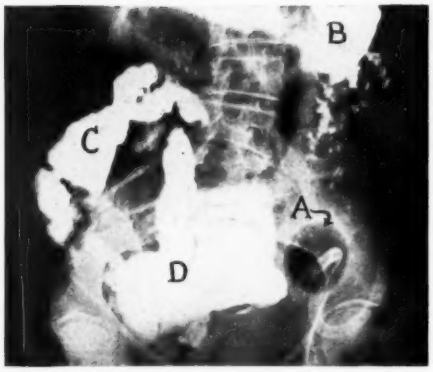

Fig. 8. Small 50 cubic centimeter capacity balloon tube used through loop colostomy in sigmoid colon—24 hour film, 84 year old patient with general gastrointestinal hypomotility. *A*, Inflated balloon; *B*, barium in descending colon; *C*, barium in ascending and transverse colon; *D*, barium in small bowel. No barium passes into the rectosigmoid or rectum.

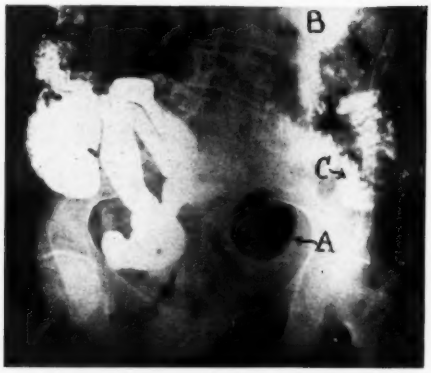

Fig. 9. Same patient as in Figure 8—32 hour film. *A*, Inflated balloon; *B*, barium in descending colon; *C*, barium passing through sigmoidostomy. No barium passes the balloon into the rectum.

into the sigmoid colon just beneath the level of the fascia. It was inflated with 40 cubic centimeters of air (the necessary amount of air to obstruct this portion of colon) and kept there for 3 days. Each day, an endoscope was inserted and the mucosa was inspected. There were no untoward effects upon the mucosa by the balloon.

The bacterial content of the defunctionalized colon was then determined. This was done in 3 patients in the following manner. An enema of 250 cubic centimeters of normal saline solution was given twice daily through the main lumen of tubing into the segment of bowel distal to the balloon. These washings were then siphoned off. A few cubic centimeters of the last washing each day were obtained for a culture and colony count. The culture, of course, was already diluted by the washings. This was done on 3 patients. Within 48 hours, the washings returned clear and were devoid of gross fecal particles. In the first patient, the bacterial count dropped from 317 colonies of Bacillus coli per plate, to 19 colonies per plate, in the first 6 days. Within the next 4 days, only saline washings being used, the count dropped to 3 colonies per plate. This patient had an inoperable carcinoma of the splenic flexure. The second patient had an obstructive carcinoma of the rectum. The washings were done through a cecostomy, some of which leaked through the rectum. The predominant organism was Bacillus proteus which was reduced from 200 to 8 colonies in 9 days. The third patient had a carcinoma of the rectosigmoid with a permanent loop sigmoidoscopy. The washings were run through the sigmoid and cultures were obtained from the fluid expelled through the anus. In this patient, the count, at first, dropped from 189 colonies Bacillus coli, to 93 colonies and then abruptly rose. It was found that the balloon had ruptured and that contaminated feces were flowing over through the rectum.

Since the bacteriological studies on these few cases were not carried out with uniform dilutions, it is recognized that the results obtained cannot be conclusive. The consistent observations, however, certainly indicate a tendency toward debacterialization. This will be substantiated by further studies.

METHOD OF USE

A cecostomy, transverse colostomy, or sigmoidoscopy is done as a preliminary procedure, according to the position of the lesion. When the bowel has been well sealed off, from the peritoneal cavity, usually, in about 5 days, the tube is placed so that the balloon will be 4 to 5 inches distal to the opening in the bowel (Fig. 3). This prevents the balloon from obstructing the outlet in the colon and also, if it is a cecostomy, from obstructing at the ileocecal valve. The tube should be held in place by adhesive taping (Fig. 10). This prevents the balloon from being drawn farther into the colon by peristalsis. The balloon is then inflated with the amount of air previously determined to obstruct the bowel at the segment in which it is inserted (90 cubic centimeters in the ascending colon and 40 cubic centimeters in the sigmoid). Collodion is placed around the wound

Fig. 10. Tube in place through cecostomy held by adhesive. Position of tube when not in use for irrigations. Main lumen open. This may be attached to drainage bottle.

Fig. 11. Method of washing the distal segment of colon by gravity.
A titrated solution of sulfasuxidine may be used.

to prevent excoriation of the skin by feces. Washings are then begun two or three times a day with any type of cleansing solution, through the main lumen of the tube (Fig. 11). A titrated solution of sulfasuxidine may be used. These enemas are siphoned off. Within 7 to 10 days, the bowel should be well defunctionalized and ready for the main operative procedure.

During, and at least 5 days after, the operation, if an anastomosis has been done, the tube should be kept intact and inflated. During the entire period, it is necessary to test the balloon daily to determine whether it is still intact. This is done by removing the clamp from the balloon portion of the tubing and attaching a loose 20 cubic centimeter syringe. If the balloon is all right, peristalsis will be in evidence by the motion of the obdurator of the syringe. Dressings on the abdomen around the tube are changed usually at the time when colon washings are given. If the opening in the large bowel fits very snugly around the tube, it is occasionally necessary to dilate this with a Kelly clamp. When it is thought that the bowel is well healed, the balloon is deflated and the tube withdrawn. The colostomy may then be closed. The bowel then assumes its normal continuity.

RESULTS

The clinical experiments for this method of defunctionalization of the colon were done in 6 patients. Four of these were inoperable. Three patients had carcinoma of the rectosigmoid, 2 of the splenic flexure, and 1 of the rectum. Four of these patients had cecostomies and 2 loop sigmoidoscopies. The four cecostomies were done for complete obstruction. Both sigmoidoscopies were palliative procedures for inoperable malignant lesions.

Three of these patients had the tube inserted and inflated. Barium was given by mouth and serial x-ray pictures taken up to 48 hours. In all 3, no barium passed the inflated balloon. All of it made exit through the respective colostomies. In 2 patients, one a cecostomy and one a sigmoidoscopy, 200 cubic centimeters of barium was injected through the bowel opening around the tube into the proximal segment under pressure. No barium passed the balloon by fluoroscopy. In 2 patients, both with colostomies, approximately 400 cubic centimeters of barium were instilled through the main lumen of the tube into the distal segment of bowel. The patient was placed in an upright position for 45 minutes. There was no back flow of barium around the balloon into the proximal segment. This was sufficient evidence to illustrate the effectiveness of a balloon to obstruct the passage of feces in the colon.

There were no complaints by any of these patients of pain due to distention of the colon by the balloon. There was no objective evidence of impairment of blood supply. Mucosal necrosis by the contact of the inflated balloon on the bowel was not observed endoscopically in one patient. It was observed that after repeated washings of the distal segment of bowel for 48 hours, the returns were clear with no macroscopic fecal particles in 3 patients. However, the decontamination of the distal segment of colon has not been conclusively proved. Results suggesting debacterialization have been obtained in preliminary studies. The ideal tube and balloon for this procedure have not, as yet, been constructed.

There were only 2 operable lesions in these 6 cases. The first patient had a carcinoma of the rectosigmoid for which a preliminary cecostomy was done for obstruction. The tube was inserted 5 days before operation and irrigations were done. The patient had an abdominal resection of the rectosigmoid by Hartman's method, with a permanent left colostomy. During resection of the lesion, the bowel was inadvertently torn with contamination of the peritoneal cavity. Sulfanilamide was used in the peritoneal cavity. The tube was removed 5 days after operation and the feces allowed to exit from the colostomy. The patient had an uneventful convalescence with no clinical evidence of infection.

The second patient had a carcinoma of the splenic flexure with obstruction. A preliminary cecostomy was done. Fourteen days after this, the tube was inserted and inflated, and irrigations with a triturated solution of sulfasuxinate were used twice daily. Five days after the insertion of the tube, the splenic flexure with the carcinoma was excised, and an end-to-end anastomosis was done. At the time of operation, the colon was collapsed. The resected portion was opened and found to be devoid of gross feces. Five days after operation, the balloon was deflated, and the tube was removed. The patient had an uneventful convalescence.

Another patient with an inoperable carcinoma of the rectum had a preliminary cecostomy for obstruction. On admission to the hospital, the malignant growth was tremendously inflamed so that it was impossible to do a rectal examination. After cecostomy, some of the inflammation subsided, but the patient developed a diarrhea of 14 to 16 small, bloody, mucoid stools a day. The tube was inserted through the cecostomy and inflated. Within 48 hours, there were no stools passed per rectum. Within 1 week, rectal examination could be done and it was found that the inflammation had almost completely subsided.

SUMMARY AND CONCLUSION

A new method has been devised to defunctionalize the colon according to Devine's precepts. It is an extremely simple procedure, which uses only a colostomy in any portion of the colon proximal to the lesion plus a special double lumen tube with a balloon attached. This functionally divorces one portion of the bowel from the other. Inasmuch as the preliminary colostomy is usually constructed prior to resection of the distal three-fourths of the colon, especially if obstruction is present or imminent, this simplified method of defunctionalization entails no additional operations nor anesthesia. The colon does not have to be disconnected. This procedure may be used for any lesion distal to the beginning of the ascending colon and need not be limited just to the distal portion of the large bowel. It is primarily an aid to resection and anastomosis of portions of the colon. Its possibilities could be extended to use in inflammatory lesions of the large bowel such as acute diverticulitis. As was pointed out in one case, it materially aids in the alleviation of the inflammatory process associated with malignant diseases of the colon. This sometimes converts an inoperable into an operable lesion.

This method of defunctionalization of the colon has been used experimentally in 6 cases, with results justifying its continuance with further observation.

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RECTOURINARY FISTULA

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SHORTLY after the close of the Revolutionary War, Anthony Fothergill, a respected Quaker physician, wrote concerning the passage of gas and fecal matter with the urine: "In young subjects the disease might in some instances, though never without great difficulty, be cured by a course of ass's milk and of Bristol water together with a course of wild balsamic injections. In old age, though the disease is incurable, yet it is of consequence to the physician, as well as to the patient and his friends, that a right judgment should be formed of its nature and probable event. This end, however, can only be obtained from such singular cases being faithfully reported when they occur" (4).

Little progress, however, was made in the treatment of this distressing malady until the latter half of the nineteenth century when diversion of the fecal stream by means of colostomy was first suggested and practiced (1, 2, 5). By 1888, Harrison Cripps in his classic monograph was able to record 63 collected cases. Forty-eight of these were of inflammatory origin, 9 cancerous, 2 traumatic, and the remainder doubtful.

Improvement in diagnostic methods and prompt surgical intervention have materially lessened the incidence of inflammatory fistulas between the rectum and the urinary passages. The advent of perineal and transurethral-prostatic surgery, however, has more than compensated for this loss. This report deals with 18 cases of rectovesical and rectourethral fistula observed within the last 21 years at the Beth Israel and the Montefiore Hospitals. Thirteen patients were observed and treated by me; 5 cases were discovered at autopsy. There was only 1 female, a woman with a large carcinomatous rectovaginovesical communication.

ETIOLOGY

The causative factor in these 18 cases was determined, as follows: traumatic, 8 cases; inflammatory, 4 cases; neoplastic, 6 cases; doubtful, 1 case.

One traumatic fistula following operation for prostatic carcinoma is also included among the neoplastic cases.

Seven fistulas resulted directly from surgical trauma and another followed an incomplete perineal excision of a large prostatic carcinoma.

From the Genitourinary Surgical Service, Beth Israel Hospital, New York City.

In Case 1 a resident surgeon noticed rectal bleeding after passing a sound, and in Case 2 the beak of a cystoscope passed by a general surgeon entered the rectal lumen (10). The perforations during transurethral prostatic resection were also made by junior surgeons and may properly be attributed to limitations in skill.

The perineal prostatectomies, on the other hand, were performed by experienced urologists. In one of these (Case 5, Beth Israel Hospital No. 150309) there was no evidence of rectal injury at the time of operation. On the 12th postoperative day there was a brisk hemorrhage into the bladder and on examination a large hiatus was found leading from the bladder into the rectum. This fistula was thought probably due to late necrosis of the thinned out rectal wall.

In Case 6 (Beth Israel Hospital No. 148496) convalescence was uneventful until the 16th postoperative day when an inexperienced nurse asked the patient to insert a rectal thermometer. The thermometer was lost and when later recovered was found to have perforated the anterior rectal wall.

The third fistula, complicating perineal prostatectomy, occurred in a case of prostatic carcinoma operated at a well known urological clinic. Total extirpation was impossible and after a short in-

TABLE I.—ETIOLOGY OF RECTOURINARY FISTULA

A. Traumatic
   1. Instrumental
      a. Perforation by sound (Case 1)
      b. Perforation by cystoscope (Case 2)
   2. Postprostatectomy
      a. Transurethral resection (Cases 3, 4)
      b. Perineal prostatectomy
         (1) Benign (Cases 5, 6, 18)
         (2) Carcinoma (Case 7)

B. Inflammatory
   1. Acute infection
      a. Prostatic abscess (Case 8)
      b. Perirectal abscess; imperforate anus (Case 9)
   2. Chronic ileitis; ileorectovesical fistula (Case 10)
   3. Tuberculosis of bladder with calculus (Case 11)

C. Neoplastic
   1. Prostatic carcinoma; perineal operation (Case 7)
   2. Rectal carcinoma; discovered at autopsy (Cases 12, 13, 14, 15)
   3. Ovarian carcinoma; rectovaginovesical fistula; discovered at autopsy (Case 16)

D. Doubtful
   1. 2 separate fistulas (Case 17)

Fig. 1. Case 8. Radio-opaque solution injected into bladder outlining rectum and colon.

terval, gas and fecal matter appeared in the urine.

SYMPTOMS AND DIAGNOSIS

The passage of gas and fecal matter with the urine or the presence of urine in the rectum indicates the existence of a communication between the bowel and the urinary passages. Gas alone in the urine, however, is known to occur in certain rare bladder infections. Some fistulas possess a ball-valve-like action, allowing free passage in but 1 direction, as in Case 10, in which fecal matter seeped into the bladder without demonstrable urinary leakage into the rectum. The presence of highly infective fecal matter in the bladder usually gives rise to cystitis and pyelonephritis with their attendant symptoms.

The injection of colored or radio-opaque solutions into the bladder or rectum is also of value in proving the existence of an abnormal communication. However, short fistulas of large diameter between the rectum and the urinary passages are themselves rarely visualized on the x-ray film. A contrast solution, injected into the bladder or urethra, flows freely through such a wide communication, speedily outlining the rectum and sigmoid colon (Fig. 1). On the other hand, the longer and more tortuous fistulas, due usually to inflammatory disease, may often be clearly delineated by the ingestion of barium (Fig. 2) or the injection of iodized oil.

TABLE II.—ACUTE RECTOURINARY FISTULA—6 CASES

Case	Cause	Treatment	Result
1	Passage of a sound	Urethral retention catheter	Cured
2	Cystoscopy	Urethral retention catheter	Cured
3	Transurethral prostatectomy	Urethral retention catheter Colostomy Suprapubic cystostomy	Failed: died carcinoma of lung
5	Perineal prostatectomy	Urethral and suprapubic catheter	Failed
6	Perineal prostatectomy. Postoperative thermometer perforation	Urethral and suprapubic catheter	Failed
8	Prostatic abscess perforating into rectum	Perineal drainage of abscess and urethral retention catheter	Cured

The size and location of a fistula are accurately determined by rectal palpation and by cystoscopic and proctoscopic examination. Punch biopsy often establishes the presence of neoplasm or tuberculosis. The possibility of multiple fistulas should not be overlooked (Case 17).

TREATMENT

Acute fistula. The immediate treatment of a recent rectourinary fistula is concerned with: (1) control of hemorrhage, (2) urinary drainage by urethral or suprapubic catheter, (3) constipation by diet and drugs, (4) intestinal bacteriostasis (sulfasuxidine, sulfaguanidine).

Results. Simple measures, such as an indwelling catheter and induced constipation, resulted in permanent closure in 3 of the 6 cases of acute fistula (Table II).

On the other hand, a rectourethral fistula, 1 centimeter in diameter, resulting from a transurethral prostatectomy, persisted despite colostomy and suprapubic cystostomy. Reparative perineal operation was prevented in this case by the coincidental development of a fatal pulmonary carcinoma (Case 3). This fistula, as well as the two which complicated perineal prostatectomy (Cases 5, 6) were short and of large diameter, the posterior urethra and rectum being in close apposition. Such fistulas are less likely to close spontaneously than are the long narrow tortuous tracts usually resulting from inflammatory disease (3, 7).

Both fistulas which followed perineal prostatectomy failed to heal despite urethral and suprapubic catheter drainage but were later cured by perineal reparative operation.

TABLE III.—CHRONIC RECTOURINARY FISTULA —9 CASES

Case	Cause	Treatment	Result
9	Perirectal abscess Imperforate anus	Colostomy	Cured
10	Chronic ileitis with ileo-rectovesical fistula	Sigmoid colostomy. Ileotransverse colostomy with exclusion of distal ileum. Suprapubic cystostomy	Improved
11	Vesical and renal tuberculosis with calculus	Suprapubic cystolithotomy	Failed. Died
4	Transurethral resection	Indwelling urethral catheter	Cured
5	Perineal prostatectomy	Sulfasuxidine. Suprapubic cystostomy. Perineal repair.	Cured
6	Perineal prostatectomy. Postoperative thermometer perforation	Sulfasuxidine. Suprapubic cystostomy. Perineal repair	Cured
7	Perineal prostatectomy for prostatic carcinoma	Colostomy. Radiotherapy. Bilateral orchidectomy	Failed. Died
17	Unknown	Colostomy. Suprapubic cystostomy. Perineal repair	Cured
18	Perineal prostatectomy	Perineal repair suprapubic cystostomy	Cured

Fig. 2. Case 10. Rectovesical fistula visualized following barium enema. Note barium in bladder. An ileotransverse colostomy had been made.

Chronic fistula (Table III). The treatment of chronic rectourinary fistula may be considered under 3 headings: (1) diversion of the fecal stream, (2) diversion of the urinary stream, (3) surgical repair.

Diversion of the fecal stream by means of colostomy can be effective only if the colostomy is complete and situated proximal to the site of the fistula. For example, in Case 10 in which there was an ileorectovesical communication, a colostomy could obviously not succeed in diverting the ileal contents from the bladder. In this instance, an ileotransverse colostomy with exclusion of the distal ileum in addition to a sigmoid colostomy proved effective.

Diversion of the fecal stream is commonly followed by prompt amelioration of the urinary infection and by an improvement in general health. Sulfa drugs are efficacious. Control of urinary infection may result in spontaneous closure especially in fistulas of inflammatory origin (Case 9).

Colostomy is urged by some authors as a routine measure preliminary to reparative closure (6). Although this has doubtless been of value in the past, the effectiveness of bacteriostatic drugs, such as sulfasuxidine and sulfaguanidine, has led me to believe that now colostomy may often be unnecessary. In 3 patients (Cases 5, 6, 18) a perineal reparative operation was done after preliminary preparation with sulfasuxidine. Both fistulas were cured without the additional risk and distress of a colostomy.

Diversion of the urinary stream by means of an indwelling urethral catheter or a suprapubic cystostomy is sometimes followed by spontaneous closure in both acute and chronic fistulas (Cases 1, 2, 4). The importance of preliminary suprapubic cystostomy in cases in which a plastic reparative operation is done has been stressed (6, 9). Free urinary drainage prevents irritation and undue tension on the freshly made vesical and urethral suture lines.

Surgical repair. Radical operation for the cure of rectourinary fistula consists of exposing and excising the fistulous tract and competently closing the resultant openings in the rectum and urinary passages. A rectovesical fistula may be approached abdominally or perineally. The perineal route is preferable except in the very high fistulas or in the presence of a complicating intra-abdominal lesion.

Rectourethral fistulas should be attacked from below (8, 9). The perineal operation offers good anatomical exposure and a lower morbidity and mortality.

The openings in the bladder or urethra and in the rectum, resulting from excision of the fistula,

are closed in 3 layers, without tension. Plain catgut is used for the mucosal layer of the bladder and chromic catgut for all the other suture lines. A wedge of muscular and fibrous tissue should be interposed between the sutured openings in the bladder and rectum.

The rectal suture line has been ingeniously eliminated by Young's operation (9) in which the rectum is mobilized well above the fistula and dislocated downward so that the fistulous defect is pulled outside the anus. The excess rectal mucosa including the opening is then amputated and the cut edges are sutured to the anal skin margin as in the Whitehead operation. The advantage of this procedure in forming a solid rectal wall is obvious. Unfortunately, however, it is not always feasible, especially if the fistula is high and the rectum adherent. In 2 cases (Cases 15, 17) it was impossible to mobilize the rectum sufficiently to exteriorize the fistulous defects. There was, however, enough downward dislocation of the rectum to prevent apposition of the freshly made suture lines. The continuity of the rectal sphincter was preserved. Its anterior half was freed and sutured to the prostatic capsule, interposing a muscular mass between the rectal and urethral suture lines.

Results. There were 2 failures among the 9 treated cases of chronic fistula (Table III). One was in a patient with advanced renal and vesical tuberculosis and the other was a fistula following perineal prostatectomy for a large prostatic carcinoma. The latter communication persisted to autopsy despite temporary improvement in health following sigmoid colostomy and bilateral orchidectomy. Six of the 9 chronic fistulas were cured and 1 has been greatly improved. A recto-urethral communication resulting from a perirectal abscess closed spontaneously almost 10 years after colostomy (Case 9). Another fistula which followed a transurethral resection healed promptly with an indwelling catheter (Case 4).

Five patients were subjected to radical reparative surgery. One of these was operated upon abdominally, the rest by the perineal approach.

CASE 10. (Montefiore Hospital No. 33186.) This 32 year old man entered the Montefiore Hospital on January 17, 1941, complaining of the passage of fecal matter and gas in the urine. He had suffered from lower abdominal cramps and diarrhea, associated with nausea and vomiting, for almost 9 years. In December, 1932, he submitted to an appendectomy and cholecystectomy at the Metropolitan Hospital. The pathological report was chronic cholecystitis and chronic granulomatous appendicitis. The symptoms continued, however, and in May, 1940, the patient noticed that he was passing food particles and gas in his urine. At a local sanatorium on December 25, 1940, an ill considered attempt was made to close the supposed rectovesical fistula. The bladder was opened suprapubically, the edges of the fistula freshened and closed with several layers of sutures passed through papillomatous tissue surrounding the fistula. These sutures gave way promptly and since then fecal matter and gas had been passed through the urethra and through the persistent suprapubic fistula.

Physical examination and roentgenographic study at the Montefiore Hospital established the existence of an ileorectovesical fistula due probably to chronic ileitis.

The abdomen was explored on March 5, 1941, and a large inflammatory mass involving the rectum, bladder, and terminal ileum, was found. The ileum was dissected from the bladder cutting across the fistula. The densely adherent rectum and bladder, however, could not be separated. The terminal ileum distal to the fistula was completely obstructed by granulomatous and fibrous tissue (chronic ileitis). The fistulous openings in the bladder and ileum were closed and a side-to-side ileotransverse colostomy was done. A double barreled sigmoid colostomy and a suprapubic cystostomy were also done. The suture line closing the fistulous opening in the ileum gave way, and fluid feces were discharged through the lower end of the wound and into the bladder.

At a second operation on April 1, 1941, the ileum was transected distal to the ileotransverse colostomy, the ends being closed in 3 layers. The suture lines held, and no more fecal matter or gas has since appeared in the bladder or from the wound. The urinary infection quickly subsided. Methylene blue injected into the lower sigmoid colostomy opening on April 16 promptly appeared in the bladder. On repetition 1 week later, however, no blue appeared in the bladder. The suprapubic sinus closed rapidly following removal of the cystostomy tube and on May 16, 1941, the patient left the hospital considerably improved with a functioning sigmoid colostomy.

The patient entered the Beth Israel Hospital (No. 132981) on June 26, 1941. He had been well for the past month and repeated tests failed to demonstrate any communication between the bladder and the rectum. At cystoscopy on June 30, 1941, a shallow pouch was seen at the right side of the trigone. This pouch, representing the site of the fistula, appeared well healed, and attempts to pass a catheter were unsuccessful. Blue solution, injected into the bladder under pressure, did not appear in the rectum. Since there was now no evidence of any fistulous communication, the sigmoid colostomy was closed by Dr. S. Standard on July 2, 1941. The colostomy remained closed, but on the 6th postoperative day the patient again noticed the passage of gas through the urethra. A barium enema proved the existence of a rectovesical communication, and on July 18 a transverse colostomy about 4 inches distal to the ileotransverse colostomy was made by Dr. Standard. The patient left the hospital on August 14, 1941.

Since leaving the hospital he has voided normally and has never passed urine through the rectum. Colored solution injected into the bladder also did not appear in the rectum. On the other hand, during 1942 colored solution did seep into the bladder following a distention enema. In 1943, however, colored enemas no longer appeared in the urine. The fistula had been electrocoagulated cystoscopically and at subsequent cystoscopic examinations no evidence of communication could be found. On December 22, 1943, however, an effervescent blue solution was injected into the rectum, and a short time later the patient passed a few colored gas bubbles through the urethra. A perineal reparative operation has been advised.

This case of ileorectovesical fistula illustrates the importance of accurately determining the

location of the fistula. A previous attempt at operative closure was doomed by failure of the surgeon to recognize the participation of the ileum in the fistula.

Following diversion of the fecal stream by ileotransverse colostomy with exclusion and sigmoid colostomy, the rectovesical fistula contracted so that urine never leaked into the rectum. On the other hand, colored enemas flowed freely into the bladder. The fistula contracted still further so that distention enemas no longer appeared in the urine. The fistula was apparently water-tight in both directions. However, its patency to gas was proved by the injection of an effervescent solution into the rectum.

CASE 5. (Beth Israel Hospital No. 150309.) This 65 year old man had undergone a perineal prostatectomy on October 8, 1942. On the 12th postoperative day, there was a brisk hemorrhage into the bladder and on examination a large communication was found between the bladder and the rectum.

The patient re-entered the hospital on February 4, 1943, for the repair of a circular rectovesical fistula about 2 centimeters in diameter. He suffered from chronic azotemia and was prepared preoperatively with intravenous fluids, a blood transfusion, and a 2 weeks' course of sulfasuxidine, a total of 67.5 grams being administered.

On February 18, the fistula was exposed perineally and the rectum was separated from the bladder. The vesical opening was closed in 2 layers. The rectum was mobilized well above the fistula and pulled downward. The opening in the rectum, however, could not be exteriorized and was closed with 3 layers of fine chromic sutures. The rectal sphincter was partially mobilized and sutured to the prostatic capsule interposing a muscular wedge between the vesical and rectal suture lines. A suprapubic cystostomy had previously been done.

The postoperative course was uneventful, the perineal wound healing well. Colored solution injected through the urethra on the 12th postoperative day appeared through the suprapubic tube but not in the rectum. The suprapubic tube was removed but a small sinus persisted which was operatively closed on March 11. Sulfadiazine was administered, and on March 29 the patient left the hospital voiding through the urethra with good control. There was no evidence of rectovesical fistula, and the suprapubic and perineal wounds were healed. A moderate degree of azotemia persisted. The patient was fairly well when seen on October 12 and November 4, 1943, despite a chronic pyelonephritis with azotemia. There was no rectovesical communication. Rectal control was normal.

The patient re-entered the hospital on January 29, 1944, with severe azotemia and acidosis. The rectal wall was firm, but there was a small perineal sinus from which pus and urine drained. Despite temporary improvement the patient died on January 31.

At autopsy the site of the former rectovesical fistula was indicated by a firmly healed radiating gray scar in the rectum. A small perineal fistula communicating with the posterior urethra was found. The right kidney was small weighing 75 grams. The pelvis and calyces were dilated but little parenchyma remained. The left kidney was also hydronephrotic, the pelvis and calyces being distended with creamy pus. The cortex was riddled with abscesses.

Case 6. (Beth Israel Hospital No. 148496.) This 62 year old man was subjected to a perineal prostatectomy on October 4, 1941. The postoperative course was uneventful until the 16th postoperative day when the anterior wall of the rectum was perforated by a thermometer. The patient left the hospital, however, on October 29 voiding through the urethra with good control. At times he noticed the passage of urine through the rectum.

The patient re-entered the hospital on December 7, 1942, for surgical repair of his rectourethral fistula. He was prepared with sulfasuxidine, 30 grams being administered in 4 days. On December 17, the fistula was excised by the perineal route, the bladder being separated from the rectum. The opening in the urethra was closed with 2 layers of chromic catgut sutures and then reinforced with 2 additional layers. The rectum was mobilized well above the site of the fistula and pulled downward, thus exteriorizing the fistulous opening. The redundant rectal mucosa was then excised and the cut edges were sutured to the anal skin. In addition, a suprapubic cystostomy was carried out.

The postoperative course was smooth, the perineal wound healing well. The suprapubic tube was removed on the 23d postoperative day, and 2 days later the suprapubic fistula was healed.

The patient left the hospital on January 12, 1943, voiding through the urethra with good control. There was no evidence of any rectourinary communication and the perineal and suprapubic wounds were healed. The fistula has remained healed, and the patient was well when last seen on February 3, 1944. Rectal examination revealed no evidence of fistula. Rectal control was normal.

Case 17. (Beth Israel Hospital No. 158216.) This 49 year old man entered the hospital on November 12, 1943, with a large rectourethral fistula easily admitting the index finger and a second smaller fistula, 0.5 centimeter in diameter, between the rectum and the trigone. He had been ill for 16 years, complaining of abdominal pain, weakness, and anemia. Eight years ago he suffered from repeated rectal hemorrhages and shortly thereafter an anal fistula was discovered and excised. In May, 1941, he suddenly began to pass gas, fecal matter, and blood through the urethra, and at the same time blood and urine were discharged from the rectum. Rectovesical fistulas were found and a bilateral vasectomy was done at the Brooklyn Jewish Hospital. The patient was told that no operation would be done for the cure of the fistulas.

The patient then entered the New York Hospital, complaining of severe pain in the urethra. Despite careful study including biopsy, the cause of the fistulas could not be determined. At proctoscopy the instrument could be inserted from the rectum into the bladder. It was felt that the fistula was far too large to attempt repair and that, even if successful, urinary incontinence would be likely. A double barreled sigmoid colostomy was done with some relief. Fecal matter and gas no longer appeared in the urine. Most of the urine, however, continued to flow through the rectum, when first seen by the author on November 1, 1943.

Rectal examination disclosed a large rectourethral fistula and a second smaller rectovesical fistula. Excretory urography showed a normal upper urinary tract and by cystoscopy confirmation of the size and location of the fistulas was made.

Suprapubic cystostomy was done on November 15 and immediately thereafter perineal repair was attempted. The large rectourethral fistula was exposed and excised. The visualization of the rectovesical fistula, however, was accomplished only with great difficulty. The rectum was dissected from the bladder well above the superior fistula and dislocated downward. The inferior fistulous opening was thus exteriorized, the redundant rectal mucosa being

amputated. The superior fistula, however, could not be brought down far enough for exteriorization. This opening in the rectum was closed in 3 layers with interrupted chromic sutures. The opening in the urethra was closed in 2 layers of interrupted chromic sutures over a Foley catheter. The opening in the bladder was also closed in 2 layers with interrupted chromic sutures and reinforced with remnants of the prostatic capsule. The anterior half of the anal sphincter was mobilized and sutured to the prostatic capsule, interposing a muscular wedge between the rectal and the urinary suture lines.

The postoperative course was smooth, the wounds healing promptly. The patient left the hospital on November 27 with the cystostomy tube in place. On December 4, the cystostomy tube was clamped and blue solution injected into the bladder. The solution was voided through the urethra with good control and none appeared in the rectum. Examination disclosed a solid rectal wall. A week later blue solution was injected into the rectum and none appeared in the urine. The suprapubic tube was removed, and on December 15 the suprapubic wound was healed. Since then the patient has voided through the urethra with good control and there has been no leakage into the rectum. On December 15 the wounds were healed and the rectal wall was firm. A colored effervescent enema did not appear in the urine.

CASE 18. (B. I. H. No. 161792.) This 62 year old man was subjected to perineal prostatectomy on March 9, 1943, in a midwestern hospital. He developed a gas infection with gangrene and necrosis of the perineal wound and scrotum, with crepitation up to the clavicle on both sides. Wide incision, radio therapy and Bacillus welchii antitoxin cleared up the gas infection. The wound healed by granulation, but there was a persistent rectourethroperineal fistula.

On January 5, 1944, the original surgeon made an effort to dissect out the fistulous tract but without success. On February 12, the urethral fistula was electrocoagulated transurethrally, without benefit.

When I first saw the patient on March 30, 1944, he voided about half his urine through the rectum. On examination, an opening could be felt in the anterior rectal wall 2.5 centimeters above the anus. The perineum and scrotum were largely replaced by scar tissue. Cystourethroscopy visualized a fistulous opening in the distal portion of the posterior urethra. There was also a small perineal fistula. Rectal control was normal, but there was a partial urinary incontinence.

Following a preliminary course of sulfasuxidine, the fistula was exposed and excised perineally on April 3, 1944. The rectum was mobilized and separated from the bladder and urethra. The defect in the urethra was sutured in 3 layers over a catheter. The rectum was dislocated downward, the fistulous opening exteriorized, and the redundant mucosa excised. The cut edges were sutured to the anal skin. The perineal wound was left wide open and a suprapubic cystostomy was done.

Convalescence was smooth, the perineal wound filling in rapidly with granulation tissue. The suprapubic tube was removed on the 15th postoperative day, and the suprapubic sinus was healed in 24 hours. The patient voided through the urethra with a good stream. There was no leakage through the perineum and the rectal wall was solid. Blue solution injected into the bladder was voided through the urethra and did not appear in the rectum or in the perineum. There was, however, partial urinary incontinence.

The patient left the hospital on April 26, 1944, with good rectal control. The perineum was practically healed and the fistula cured.

SUMMARY

Surgical trauma and neoplasm were the most frequent causes in 18 cases of rectovesical and rectourethral fistula.

The passage of gas and fecal matter with the urine or the presence of urine in the rectum indicated a communication between the bowel and the urinary passages. The size and location of the fistulas were determined by rectal palpation and by cystoscopic and proctoscopic examinations. The injection of colored and radio-opaque solutions served as a valuable confirmatory diagnostic measure. In 1 case an effervescent colored enema demonstrated a tiny communication when other methods failed.

Six rectourinary fistulas were observed during the acute stage shortly after perforation. The immediate treatment of such a fistula was concerned with control of hemorrhage, adequate urinary drainage, induced constipation, and intestinal bacteriostasis. Three of the acute fistulas were cured by these simple measures.

Five of the 9 cases of chronic rectourinary fistula were subjected to radical reparative operation. Suprapubic cystostomy was a routine preliminary measure. On the other hand, the preoperative administration of sulfasuxidine eliminated the need for colostomy in 3 cases. Colostomy served as an effective palliative measure in 3 inoperable cases.

An ileorectovesical fistula was operated upon abdominally and 4 rectourinary fistulas were successfully repaired by the Young perineal technique. A modification was introduced in 2 cases in which the rectal fistulous opening could not be exteriorized. The anterior half of the preserved rectal sphincter was mobilized and sutured to the prostatic capsule, interposing a muscular wedge between the vesical and rectal sphincter lines. Rectal control was unaffected.

CONCLUSIONS

Rectourinary fistulas due to trauma or acute inflammatory disease frequently heal with conservative treatment. On the other hand, those which are caused by neoplasm offer a grave prognosis.

Chronic rectovesical and rectourethral fistulas are best approached and repaired by the perineal route. The fistulous opening in the rectum can often be exteriorized and excised with the redundant mucous membrane. If this is not feasible, the freshly sutured defects in the bladder and rectum should be separated by an interposed muscular wedge. The rectal sphincter can safely be used for this purpose.

Suprapubic cystostomy is indicated prior to radical reparative operation. On the other hand, preoperative administration of sulfasuxidine has enabled the author to abandon preliminary colostomy as a routine measure.

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THE USE OF VENOUS TOURNIQUETS AS AN AID TO THE DIAGNOSIS OF INCIPIENT TRAUMATIC SHOCK

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THE need for a method that will aid in the detection of incipient traumatic shock has been repeatedly emphasized. The decline in blood volume which occurs in the early stages of traumatic shock is associated with vasoconstriction and a fall in cardiac output. Because of vasoconstriction the arterial pressure usually does not decline until a later stage of shock has been reached. It is obvious, then, that it is desirable to diagnose early or incipient shock before the arterial pressure declines. The presence or absence of alterations in the pulse rate and in the concentration of the red blood corpuscles may be misleading. It is agreed by most workers in this field that one should treat shock according to the extent of injury and blood loss and the general clinical picture rather than wait for alterations in the blood pressure or pulse rate or concentration of the red corpuscles.

A test for incipient shock, if it is to be of practical value, should be simple, rapid, and reliable. The method to be described has been employed in the accident room of the Johns Hopkins Hospital for almost a year and has been of practical value. The method is simple but is not so rapid as might be desired. In a few cases it has indicated incipient shock of a greater degree than existed as judged by the subsequent course of the patient. On the other hand, the test has not failed to indicate incipient shock when it was present.

The principle underlying the method is that of reducing temporarily the effective volume of circulating blood by trapping part of the blood in the lower extremities by the application of venous tourniquets. It was reasoned that in the presence of a previous reduction in blood volume a further decline might not allow compensatory vasoconstriction to maintain the arterial pressure at the normal level.

The majority of the patients were young adults and most of them had been in good health. Patients who had a systolic pressure which was distinctly below normal were not included in the study. Although previous blood pressure determinations had not been performed, systolic levels of 104 millimeters of mercury and above were assumed to be normal. As soon as the general condition of the patient had been noted, blood pressure cuffs were applied as high as possible about both upper thighs. Some difficulty was encountered in the earlier cases in which ordinary blood pressure cuffs were applied to the thighs. Because of the conical shape of the thigh and variation in size in different patients the cuffs had a tendency to slip downward from the original position on the thigh. These difficulties were overcome by lengthening the cloth portion of the cuffs by four feet. The cuffs on the two thighs were inflated to a degree slightly in excess of the previously determined diastolic level. These two cuffs were connected in such a manner that they could be inflated simultaneously. This inflation was maintained for 5 or 6 minutes, and during this time the blood pressure in one of the arms was determined at minute intervals. The cuffs on the thighs were then deflated and several additional determinations of the blood pressure were made.

The results are divided into five groups according to the percentage of reduction in the systolic pressure that accompanied the inflation of the cuffs on the thighs. The arbitrary divisions are as follows: (1) 0 to 5 per cent reduction; (2) 5 to 10 per cent reduction; (3) 10 to 17 per cent reduction; (4) 17 to 25 per cent reduction; and (5) 25 per cent or more. These results are given in Tables I, II, III, IV, and V.

The control subjects showed little reduction in the systolic pressure in association with the inflation of the cuffs. These subjects were ambulatory normal young adults who were allowed to remain in a reclining position for 5 to 10 minutes before readings were begun. Inflation of the thigh cuffs in 17 of these subjects produced either no fall in systolic pressure or a fall amounting to less than 5 per cent of the control level. In the remaining 2 subjects the fall in systolic pressure was 6 per cent in 1 and 7 per cent of the control value in the other. In 5 of the 8 blood donors there was less than a 5 per cent reduction in the systolic pressure. Nine hundred cubic centimeters of blood

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TABLE I.—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 5 PER CENT OR LESS FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg.	Treatment	Remarks
21	Controls	Normal	None	
5	Blood donor	Normal	None	500 c.c. donations
1	Leaking ectopic pregnancy	120/64. Fell to 90/60 during operation	500 c.c. blood	Leaking ectopic with 150 c.c. blood in peritoneal cavity. Recovery.
2	Struck by automobile. Question of ruptured viscus	Normal	None	After period of observation symptoms cleared spontaneously and patients discharged
1	Vaginal bleeding from incomplete abortion	120/74	None	Given course of pituitrin. Discharged
1	Contusion of arm in washing machine wringer	116/62	None	Discharged well. No sign of serious injury to arm
1	Large laceration forehead. Moderate bleeding. Struck by automobile	138/86	None	Discharged well. No fracture of skull or intracranial injury
1	1st, 2nd, and 3rd degree burn of 20 per cent body surface	128/78	Sodium lactate 500 c.c. Plasma 500 c.c. Glucose and saline 500 c.c.	Eventually grafted over small area. Discharged well
1	Compound fracture tibia and fibula	105/84	None	Recovery
1	Stab wound chest wall	154/100	None	Recovery
3	Laceration scalp	Normal	None	Recovery

had been removed from 1 of the 3 remaining subjects. A detailed description of the other results is unnecessary since they are given in the tables. In studying these tables it is apparent that those patients with the most extensive injuries and the greatest loss of blood usually showed the greatest decline in the systolic arterial pressure when the cuffs were inflated. Furthermore, it was usually those patients who exhibited the greatest decline in arterial pressure who required the largest volume of intravenous fluids. In almost all instances the systolic pressure returned to, or almost to, the previous control level as soon as the constriction on the thighs was released.

In a number of cases the pulse rate increased when the venous tourniquets were applied. This alteration, however, was less constant than the decline in the systolic pressure.

Only one patient with burns was studied. This patient was seen a few minutes after the injury. Despite the fact that approximately 20 per cent of the body surface had been burned, there was little decline in the blood pressure following application of the tourniquets. Additional studies on this type of injury are indicated.

Studies were carried out on several patients in whom the blood pressure was at shock level at the time of studies. A considerable decline in blood pressure was noted after application of tourniquets. These cases are not included in the tables.

As stated previously, in traumatic shock the blood volume and cardiac output decline before the fall in blood pressure occurs. In recovery from traumatic shock after the administration of blood and blood substitutes, the blood pressure returns to normal before the blood volume has been restored to its previous level. It has not been fully appreciated that one should not be content with effecting a return of the blood pressure to normal but should continue treatment until an adequate blood volume has been restored. Churchill recently has stressed the importance of determining when the injured patient is in a stabilized state and can withstand operation or transportation without the development of peripheral circulatory failure. Although the test which has been described has not been adequately studied from this viewpoint, it is likely that the method will supply useful information.

In connection with these studies the experiments of Ebert and Stead are of interest. These investigators, while studying the rationale for the application of venous tourniquets in the treatment of cardiac failure, proved that a considerable quantity of blood could be trapped in the extremities by the use of venous tourniquets. When tourniquets were applied to both upper thighs and one arm for a period of 7 to 10 minutes the amount of blood contained in these extremities at the end of this time averaged 29 per cent of the previously determined total blood volume. From these observations it is clear that further reduction of the circulating blood volume of an injured patient by this method could reduce the blood

TABLE II.—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 5 TO 10 PER CENT FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg.	Treatment	Remarks
2	Controls	Normal	None	No symptoms. One showed fall in systolic pressure of 6 per cent, the other 7 per cent
3	Blood donor (one 900 c.c.)	Normal	None	Paleness and sweating. Quick recovery
2	Stab wound of thorax with evidence of pleural perforation but no hemothorax or pneumothorax	Normal	None	Weakness. One admitted overnight
1	Numerous jagged lacerations of scalp. Moderate bleeding	116/82	None	Lacerations sutured. Discharged
1	Fracture tibia and fibula	114/80	None	Recovery
1	Gunshot wound abdomen and left forearm. Perforations jejunum	130/82	1,500 c.c. saline	Recovery

TABLE III.—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 10 TO 17 PER CENT FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg.	Treatment	Remarks
1	Stab wound of chest and abdomen. Hemothorax and hemoperitoneum	106/48	500 c.c. blood. Fluid during test	Small amount of blood over liver. 180 c.c. blood aspirated from thorax
1	Stab wound of abdomen with laceration of liver	170/114	3,000 c.c. intravenous fluids	Moderate bleeding from lacerated liver
1	Stab wound of abdomen with perforation of colon	108/70	2,500 c.c. saline and glucose. Fluid during test	Exploration, suture colon, recovery
1	Bullet wound of chest and liver	138/90	None	Never developed signs of serious internal hemorrhage. Observed 7 days. Discharged well
1	Stab wound of chest with hemothorax	108/70	None	Developed hemothorax but no dyspnea or signs of mediastinal shift
1	Bilateral compound fractures both lower legs	126/82	1,500 c.c. intravenous fluids	Fractures reduced under ether anesthesia and casts applied. Discharged well.
1	Intracranial injury	106/88	None	Admitted to ward 2 hours later, still unconscious Died several days later
1	Stab wound chest. Slight hemopneumothorax	144/88	None	Recovery
1	Gunshot wounds of abdomen and chest. Injury spleen, stomach, etc.	114/70	1,500 c.c. blood	Blood pressure declined to 50/30 during operation. Died subsequently
1	Subtrochanteric fracture femur	110/54	1,500 c.c. saline and glucose	Recovery

TABLE IV.—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 17 TO 25 PER CENT FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg.	Treatment	Remarks
1	Bullet wounds of abdomen and arm. Multiple perforations of ileum and mesentery	130/92	2,500 c.c. blood. Glucose and saline also	Exploration. Resection small intestine. Blood pressure fell to 72/34 during operation. Recovery
1	Extensive laceration of hand. Moderate blood loss	108/52	None. 1,500 c.c. saline and glucose after operation	Laceration repaired under anesthesia. Seemed on verge of neurogenic shock at time of test
1	Penetrating abdominal wound. Wound face	114/80	1,500 c.c. saline-glucose solution	Blood pressure fell to 70/40 during operation. Recovery
1	Gunshot wound of femur	116/82	None	Recovery

TABLE V.—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 25 PER CENT OR GREATER FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg.	Treatment	Remarks
1	Bullet wound of abdomen with perforation of stomach. 300 c.c. blood in lesser peritoneal cavity	136/80	300 c.c. saline and glucose. 500 c.c. plasma. 500 c.c. blood	Exploration, suture perforation. Recovery
1	Bullet wound of abdomen with perforation of sigmoid and mesentery and multiple perforations of ileum	130/68	500 c.c. intravenous fluids. 1,500 c.c. blood	Resection portion sigmoid and ileum. Blood pressure dropped to 80/55 during operation. Recovery
1	Stab wound of abdomen with division of deep inferior epigastric artery	132/66	1,000 c.c. intravenous fluids. 500 c.c. blood	Exploration. No intra-abdominal injury although peritoneal cavity had been entered. Recovery
1	Bullet wound of thorax with hemothorax	124/58	750 c.c. intravenous fluids	Two days later 450 c.c. bloody fluid aspirated from chest. 200 c.c. more on following day. Patient developed empyema which was drained. Recovered
1	Struck by automobile. Fracture vertebra, 3 ribs, sacrum, pubis, and pubic ramus	104/60	500 c.c. plasma. Fluids by mouth	Treated with bed rest. General condition remained good. Recovered
1	Severe vaginal bleeding from incomplete abortion	112/48	1,000 c.c. blood	Blood pressure good on admission. Bleeding in small amounts. Hemoglobin, 34 per cent. No therapy for 6 hours with condition unchanged. Given course of pituitrin. Passed placenta. Given 1,000 c.c. blood. Discharged from hospital 4 days later well
1	Penetrating chest wound. Laceration lung	112/80	500 c.c. saline. 1,000 c.c. blood	Blood pressure fell to 70/54 with tourniquets and to 70/40 during the operation. Recovery

volume sufficiently to produce a fall in arterial pressure before it would have occurred in the ordinary sequence of changes in the development of shock.

In summary, a method has been described which appears to be useful in the diagnosis of early shock before a significant decline in the arterial pressure has occurred. The method consists in the application of blood pressure cuffs to the upper thighs and the inflation of the cuffs to a point slightly above the diastolic pressure level. An associated fall in arterial pressure if present may give a false indication of the presence of shock, but apparently it is correct in indicating incipient traumatic shock when it exists.

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LABORATORY ROUTINE FOR FLUID, ELECTROLYTE, AND PROTEIN CONTROL IN SURGICAL PATIENTS

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EARLY in 1836, Bright observed in his studies on nephritis that the protein concentration of the blood plasma was low. Csatáry (1891) found that this deficiency was due more to a low serum albumin than to a reduced globulin level so that the albumin globulin ratio, normally 1.5 to 2.5, fell below 1. During the ensuing years this reduction in the albumin globulin ratio was observed in diseases other than nephritis. Gram found wide variations in the plasma proteins in various types of liver carcinoma and we have repeatedly observed an early drop in albumin in dogs following ligation of the common bile duct. Grenet, and Gilbert and Chiray were among the first to observe decreases in the total plasma protein level in patients with cirrhosis of the liver, while Myers and Keefer studied 16 cases of cirrhosis and 14 cases of other types of liver disease showing consistent reduction in the blood protein level. Tumen and Bokus, and Foley with others found this reduction in plasma protein to be chiefly due to a hypoalbuminemia. Snell in reporting a large series of cases remarked upon the unusual rapidity with which changes in the total protein value and the albumin globulin ratio could take place and intimated that for this reason repeated observations on the blood protein level might be necessary on the same patient to be of definite prognostic value. Jones and Eaton, in 1933, first called particular attention to the dangers of hypoproteinemia in surgical patients. Following this work, Mecran, Barden, and Ravelin (13) found gastric emptying time to be delayed in hypoproteinemia even in the intact stomach and without any known deficiency of accessory food stuffs. Barden, Thompson, Ravelin, and Frank (2) found the motility of the small bowel reduced during hypoproteinemia and the intestinal motility could be restored to normal, restoring the plasma proteins to normal levels. Thompson, Ravelin, and Frank demonstrated a delay in fibroplasia in the dog in hypoproteinemia and believe that such a deficiency is a factor in the disruption of wounds, and Clark long ago found that wounds healed more rapidly and the lag period was reduced when patients were given a high protein diet.

Many attempts have been made to find easily determined measurements of the blood proteins by their physical properties rather than by their chemical analysis. Starlinger and Hartl have reviewed methods based on interferometric, polarimetric, viscosimetric, and refractometric measurements, all of which are influenced chiefly by the proteins among the plasma constituents. The time drop method of Barbour, Reiss' refractometric procedure, and Moore and Van Slyke's (14) gravimetric tests are the only physical measurements which have proved sufficiently practical to win any general use. The refractometric method has been found by Linder, Lundsgaard, and Van Slyke (12) to give rather wide errors in normal blood, while Guillaumin, Wahl, and Laurencin found even greater errors in plasma from edematous patients because of the excessive lipid content. The gravimetric method of Moore and Van Slyke, the copper sulfate method of Phillips and Van Slyke and the time drop method of Barbour yield equally accurate results when compared with Van Slyke's (21) gasometric micro-Kjeldahl procedure.

Benefits accruing from the intravenous use of erythrocytes, glucose, salt, or Ringer's solution are common knowledge. With the availability of serum proteins and recognition of their value intravenously the problem of choice of the proper intravenous medication becomes both more complicated and more important. A patient's need may become specific for any one or any combination of cells, electrolytes, crystalloids, and proteins, while the cost of serum proteins is high enough to be prohibitive unless they can be proved absolutely necessary.

By the following simple routines we have been estimating the requirements of patients for sugar, salt, fluid, blood proteins, and erythrocytes with reasonable accuracy and intravenous therapy has been more efficiently and economically used by following the results of this laboratory system than when the choice of therapy is left wholly to clinical opinion and judgment.

Fifteen cubic centimeters of blood are taken from the cubital vein of a patient needing intravenous fluid and are placed in a graduated

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centrifuge tube. Coagulation is prevented by the addition of a small amount of heparin, heparin being used because any other anticoagulent changes the specific gravity and viscosity of the plasma. At the same time a complete blood count is made from blood taken from the lobe of the ear and a sample of urine is collected. From this time, until the patient is convalescent or no longer needs fluids, each 24 hour sample of urine is saved, measured, and a 6 ounce sample preserved. The venous blood is then returned to the laboratory, placed in a centrifuge, and spun at 2000 revolutions per minute for 10 minutes. At the end of this time the erythrocytes are uniformly packed and the level of erythrocytes is read directly from the graduations on the wall of the centrifuge tube. This hematocrit level read directly gives the percentage of erythrocytes in the circulating blood and by this time the erythrocytes have been counted in the usual counting chambers. If the erythrocyte count is below 3,000,000, or the hematocrit reading below 30 per cent, transfusion of whole blood is advised on the ground that in addition to the clinical indications for fluid, erythrocytes are indicated. Furthermore, with a hematocrit reading of 30 per cent or less, there is a hemodilution and whole blood is needed. The supernatant plasma is now drawn off and albumin globulin ratio is done, and the density of the plasma is measured by the falling drop method. At the same time, a qualitative sugar and a quantitative estimation of the chlorides is done on the urine sample. The estimation of sugar in the urine is necessary in order to assure the safety of glucose administration later, if indicated. The rationale of the total chloride content of the urine is as follows: In repeated experiments with dogs and on normal as well as ill human beings, we have found that, if 4 grams or more of chloride are spilled over per day in the urine, excepting in certain types of kidney disease, the blood chlorides will be at a normal level. Inasmuch as estimation of urine chlorides is simpler, cheaper, and faster than the estimation of blood chloride and the sample is much more easily obtained, a daily estimation of urine chloride gives one an adequate idea of the circulating chloride electrolytes in the blood. While the first sample of urine taken does not accurately give the 24 hour excretion because no 24 hour sample is available, by using 1500 cubic centimeters of urine per 24 hours as a base line, even this first sample gives a reasonably accurate idea of the chloride excretion of the patient, and of the blood chloride level. Following this sample, the chloride output each 24 hours is estimated from the urine samples saved. With the hematocrit level now available, the blood count done, the urinary sugar and chloride content estimated, the albumin globulin ratio and density of the blood are estimated. From the albumin globulin ratio, the total protein of the blood is taken. If the total protein of the blood is below 5, or the albumin globulin ratio is below 1.5 to 1, plasma is indicated, regardless of the need for erythrocytes and can be given, of course, with or without red cells. The density of the blood is recorded, to be used later as a base line in blood protein fluctuations during the ensuing period of illness. Within 40 minutes of the entry of a patient into the hospital, on 15 cubic centimeters of blood and one sample of urine, and by these four reasonably quick and inexpensive laboratory tests, the groundwork has now been laid to indicate the need for erythrocytes, electrolytes, and protein. The changing conditions of the patient's circulating tissue can now be followed closely and cheaply by three daily tests. These being the measurement of the density of the plasma by the falling drop method, the daily estimation of the urinary chlorides in the urine per 24 hours, and a qualitative urinary sugar estimation. As stated previously, as long as the daily output of salt is 4 grams per 24 hours, it has been our experience that the blood chlorides will remain in the normal zone. Glucose may be given with reasonable safety except perhaps in certain types of liver disease, to, and past the point where sugar spills over in the urine. But to guard against an excessive administration of glucose, the urinary sugar is done and if the urinary sugar remains over +2 for any appreciable period of time, salt or Ringer's solution is advised temporarily to replace the glucose. With reference to the blood protein, the albumin globulin ratio and the total proteins are available from the first estimation. At that time the density of the blood was measured and establishes a base line of density against which subsequent 24 hour densities are measured. Almost without exception, any rapid drop in the blood density has been in our experience and in the experience of others, due to a drop in albumin, while any rapid rise has been due to an increase in globulin, or a decrease in total circulating blood fluid. An appreciable drop in blood density then in any 24 hour period is taken either to indicate the need for additional albumin as given by blood plasma, the existence of a superhydration from excess fluid given by vein, or insufficient fluid elimination by the body. Differentiation between these factors can be done by the clinician with, perhaps, a hematocrit reading for cell volume. A sudden rise in blood density most commonly oc-

curs from insufficient fluid administration or from a sudden rise in the globulin fraction of the plasma, and in either case water is indicated, the crystalloids in the water being determined, as stated before, by the amount of chloride and the amount of glucose in the urine. While mistakes may be made in the fluid administration in patients handled in this way, they are far fewer than those made in cases in which the plasma is not similarly followed, and while seeming somewhat involved perhaps, the actual costs of the original estimations are reasonable and the follow-up of blood density and urinary chlorides is cheap. Uniform success, of course, is not achieved even when the indications are correct, because in a certain percentage of cases we have found that the administration of plasma when definitely indicated by laboratory methods, still does not cause a beneficial response which one would expect and in a small series of cases in which this has occurred, there has been liver damage. On the other hand, the benefit of plasma in far smaller amounts than would raise the blood proteins to a normal level causes an entirely unproportional improvement in the patient's condition. We feel that with blood plasma being now as easily available to the physician and patient as are salt and glucose, the methods of control which have been described or similar methods are essential in a proper handling of intravenous therapy.

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EDITORIALS

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THE ORIGIN OF CHOLECYSTITIS

THE temptation is prevalent to use the words "inflammation" and "infection" as synonyms. There is good reason for this. For many years by far the most important cause of such inflammation that has been discussed has been bacterial action. Moreover, our knowledge of bacteria and their effect upon the organism developed almost concomitantly with our knowledge of the cellular response of the organism to injury. Such a subtle association between infection and inflammation has thus suggested that the cause of inflammation first be considered bacterial infection. The frequency in which such has been true has made this approach worthwhile.

As more has been learned about inflammation, however, and, in particular, about those substances that provoke inflammation, there becomes apparent a large group of diseases affecting the human body in which tissues are damaged without the primary mediation of a micro-organism. Many of these substances are of endogenous origin, and their action may be related to a single organ or to many viscera. Inflammation of the gall bladder seems to offer such a case in point.

It seems to have been almost immediately assumed that inflammation of the gall bladder is due to an infection. This assumption has received corroboration subsequently when the gall bladder has been cultured and organisms have often been found in its wall and in the contained bile. The type of the organisms is variable, belonging most commonly to the streptococcus and colon groups. When it was demonstrated that inflammation of the gall bladder could be produced experimentally by the injection of streptococci into the portal stream, the pathogenesis then seemed to be established.

Many phases of the clinical picture of cholecystitis, however, do not fit in perfectly with such a concept of pathogenesis. For instance, cholecystitis is relatively infrequent in children and its incidence increases very definitely as the individual becomes older. If cholecystitis were entirely bacterial in origin one would anticipate that the reverse would be true. Bacterial invasion of the portal stream is more common in younger individuals, being seen most frequently in association with acute appendicitis, peritonitis, intestinal obstruction, and the numerous dysenteries that occur in children. Cholecystitis is more frequent in women and in individuals of certain habitus, factors that would seem offhand to have no relationship whatsoever to bacterial invasion. Acute cholecystitis also is almost universally seen in the presence of obstruction of the cystic duct, and it has been well recog-

nized for years that inflammation of the gall-bladder wall is nearly always associated with cholelithiasis.

One of the earliest observers to call attention to some of the discrepancies mentioned was the late Edmund Andrews, and one of his very important contributions was the culture of the bile and the wall of normal gall bladders, the flora being compared with a similar group of acutely diseased and chronically diseased gall bladders. He and Henry were able to demonstrate that both quantitatively and qualitatively there was but little difference in the cultures of gall bladders of all types, including those with acute inflammation, and those that were microscopically normal. Often in acute cholecystitis the badly damaged gall-bladder wall was found to be sterile, as was the contained bile. This has been our experience also. Again, often microscopically normal gall bladders would be intensely infested with bacteria of many types, in fact with almost any organism that was prone to be present in the intestinal tract of that particular patient. The use of normal gall bladders as a control in studying the bacteriology of cholecystitis was extremely important and strangely enough, had been ignored by previous observers. This failure of correlation between the pathologic changes and the presence of bacteria would seem to raise a very serious factual objection to the age old assumption that cholecystitis is primarily bacterial in origin. It does establish the fact, however, that often the gall bladder like many other organs in the body is normally a contaminated viscus. This premise being true, injury to such a viscus would probably be followed many times by true bacterial infection. Such a conception raises a new problem: namely, how is this initial injury sustained?

That such a primary injury may be chemical in type has been suggested by several, for example: Mann has shown that intravenous injection of Dakin's solution would produce acute cholecystitis; Wolfer has presented evidence that pancreatic juice when introduced into the gall bladder can produce serious destructive changes, as it does in other tissues after it is activated; Andrews and his co-workers have demonstrated that the injection of bile salts into the gall bladder often resulted in acute inflammation.

Because of the very frequent association between obstruction of the cystic duct and acute cholecystitis, it occurred to us that the substance obstructed, namely bile, must play an important part in the production of this inflammation. When one considers the damaging action of bile on tissue when it is placed in the peritoneal cavity, in the pancreas, or in the subcutaneous tissues, such a conception is a plausible one.

Accordingly, we conducted experiments on dogs to demonstrate, if possible, the damaging action of bile on the gall-bladder wall. It was noted that if complete obstruction of the cystic duct was produced after the gall bladder had been emptied of its bile, and the contents replaced with physiologic solution of sodium chloride, there was no evidence subsequently of inflammation in the gall-bladder wall. Hydrops ensued. However, when complete obstruction of the cystic duct was performed and bile left imprisoned in the gall bladder, the resulting inflammation varied in severity and type in direct proportion to the content and the concentration of the bile obstructed. This inflammation was identical with that encountered in clinical cholecystitis. This damaging action did not seem to depend on any single substance in bile, but could be shown to be present when various components of the cholic acid derivatives were used. For the most part, these substances appeared to be cholesterol in its various forms, or some of the

bile salts. Of the latter group, sodium taurocholate, sodium glycocholate, and sodium desoxycholate were studied. The latter seemed to be the most damaging. In cases in which the concentration of bile or of these particular components was one time greater than that normally found in the gall bladder, in about half the instances, actual necrosis of the gall-bladder wall was seen. This amount of concentration of bile necessary to produce damage in the gall-bladder wall is physiologically possible.

These changes of an acute nature that we have observed with total obstruction of the cystic duct can be correlated with the changes of a chronic nature that Cole and his coworkers have shown to take place with incomplete obstruction of the cystic duct. From all of these experimental studies it seemed to us fair to conclude that three important factors were involved in the production of cholecystitis. These factors were: obstruction of the cystic duct, the action of bile on the gall-bladder wall, and the occasional secondary presence of bacterial infection which would be superimposed upon the chemically damaged tissue. Although at times the bacterial infection would often be so great as to overshadow all of the other factors, in all probability, it is usually preceded by the chemical damage.

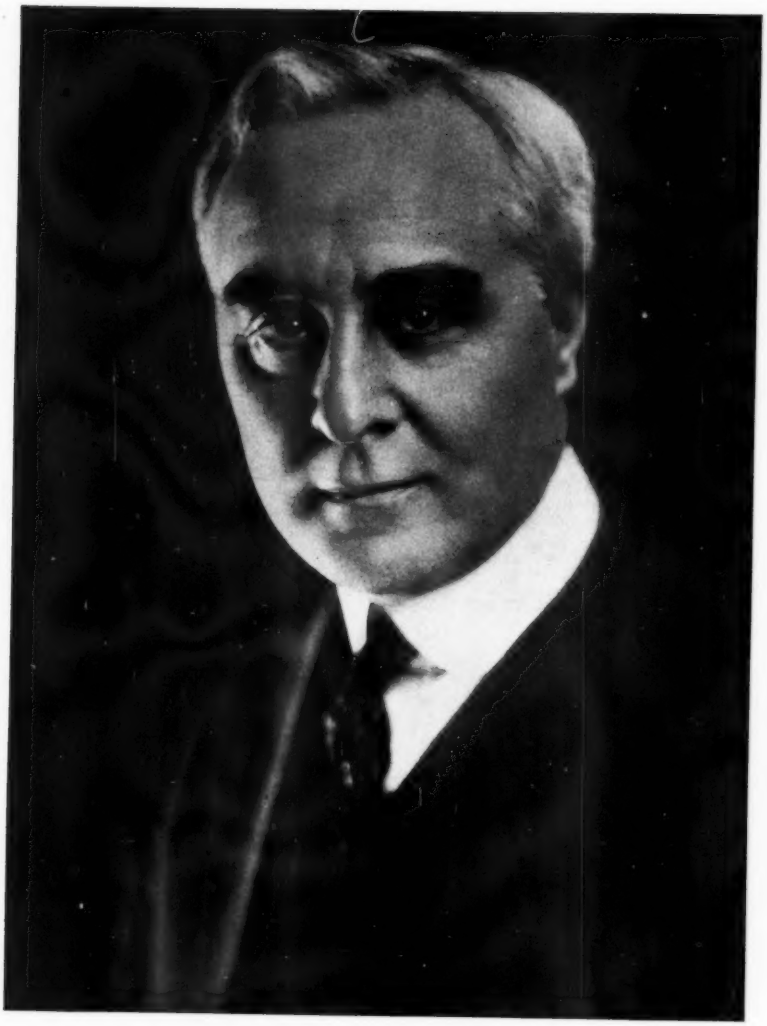
The next problem that asserted itself was to find evidence that human cholecystitis was related to the presence of bile products in the gall-bladder wall. In view of the fact that most of these chemical irritants in bile with which we are dealing are steroid in type, and that such substances often give a characteristic type of inflammatory reaction which is not seen with that produced by bacteria generally found in the gall-bladder wall, it occurred to us that a more careful study of the cellular reaction in an injured gall bladder should be undertaken. The most common infectious agents in cholecystitis belong to the streptococcus and colon groups of organisms, and one would therefore expect a characteristic pyogenic reaction in cases in which infection was predominant. This reaction was rarely found to be present. A reaction to lipoid material on the other hand, would consist generally of edema, fibroplasia, and a histiocytic response as wandering cells, xanthoma cells, or giant cells. Lymphocytes would be present and polymorphonuclear leucocytes rare. Exactly this was found.

In a recent study of 354 gall bladders which were removed consecutively in the Barnes Hospital, we were able to show that in 36, or 10.2 per cent of our specimens, lipoid material resembling cholesterol ester was found in histiocytes beneath the mucosa, giving the characteristic picture of "strawberry" gall bladder. Such a picture was, as a rule, not associated with a great amount of tissue damage in the gall-bladder wall, but was frequently found associated with cholesterol gall stones. In 80 cases, or 20.6 per cent of the gall bladders removed, there was microscopic evidence of either lipid or bile deep in the gall-bladder wall. In almost every instance these gall bladders were badly damaged, most of them showing evidence of recent acute inflammatory reaction. Thus, including cholesterolosis or "strawberry" gall bladder, there was a total of 116 cases, or 32.8 per cent of the gall bladders removed, in which one could demonstrate some histologic evidence of a lipid or bile reaction in the wall of the gall bladder.

Such a conception of the etiology of cholecystitis would consider cholesterolosis or "strawberry" gall bladder an early form of cholecystitis. It would not place it in a category apart. It would correlate the association of cholecystitis with precipitation of components of bile in the gall bladder to form

stones and the relationship of those stones to inflammation. It would explain why in the gall bladder may be found a varied group of organisms ranging from Streptococcus hemolyticus to Bacillus typhosus with the identical inflammatory reaction. The type of bacteria present in the gall bladder would depend upon those present in the intestinal tract of that particular individual, while the primary inflammatory process is of different origin. Such a concept of pathogenesis satisfies the question raised earlier concerning the many clinical characteristics found in this disease.

NATHAN A. WOMACK



FREDERIC ATWOOD BESLEY

April 19, 1868—August 16, 1944

MEMOIRS

FREDERIC ATWOOD BESLEY

THE colorful figure of Frederic Atwood Besley, its lights and shadows, is not readily portrayed in a pen picture. At best such a portrait can but recall to hundreds of colleagues and students his lovable social graces and pleasantries, his forceful teaching, and his accomplishments in the field of surgery.

Fred Besley's life and activities were identified with the immediate territory in which he was born, Waukegan, Illinois, 40 miles north of Chicago, on April 19, 1868, the son of William and Sylvia Jocelyn Besley. It was here that he developed his love of the outdoors and of horses, which he maintained all of his life.

After graduating from Northwestern University Medical School in 1894, Besley won the much coveted interneship in Cook County Hospital, an institution which, throughout its history, played a dominant rôle in shaping the careers of many prominent men of medicine, not only in Chicago but throughout the nation. Here he came under the influence of an attending staff on which were such men as John B. Murphy, Weller Van Hook, Christian Fenger, James B. Herrick, and other clinicians who were building the reputation of the young medical center of Chicago. Leaving the County Hospital, he entered general practice on the South side of Chicago, and in 1899 joined the surgical faculty of his alma mater as instructor, advancing to the rank of professor, in 1915.

In 1900 Besley was appointed professor of surgery at the Chicago Post Graduate Medical School and Hospital. Here began an intimate friendship and association with Franklin H. Martin that was to endure the entire lives of the two men. At this time began his close association with Allen B. Kanavel and Harry M. Richter, all three men being strongly influenced by Weller Van Hook, chairman of the Division of Surgery at Northwestern until 1909. Then, following through under the leadership of John B. Murphy, these three men contributed much to the development of the strong Department of Surgery at this institution, and to the surgical reputation of Wesley Memorial Hospital at that time, where they served as attending surgeons.

In 1904 Besley was appointed attending surgeon at Cook County Hospital, which position he occupied until America's entry into World War I, when he was commissioned Major and Chief Surgeon of Northwestern University Base Hospital No. 12. Serving in France, he later became Division Surgeon, and retired with the rank of Colonel.

Returning to practice and teaching in Chicago in 1919, Besley began to feel the lure of the countryside he loved so much as a boy. In 1924 he returned to Waukegan to take up practice there. With his love for organizing, he founded the Besley-Waukegan Clinic at the Victory Memorial Hospital, in which he was active until the time of his death.

A founder member of the American College of Surgeons, Besley served this organization many years as treasurer, president, member of the Board of Regents, and from 1938 as secretary until the time of his death. In 1905, with Franklin Martin, Allen B. Kanavel, John Hollister and William R. Cubbins, he served as founder member on the Editorial Board of SURGERY, GYNECOLOGY AND OBSTETRICS, and continued actively on that board from the time of its establishment.

In his later years, Besley became interested in traumatic surgery, becoming the first chairman in 1926 of the Committee on Industrial Medicine and Traumatic Surgery of the American College of Surgeons, serving in this capacity until 1939. He was a Fellow of the American Surgical Association and a member of the Chicago Surgical Society.

This, very briefly, is the sketch of a man who, throughout his professional life, was continuously active in advancing the frontiers of surgery. His surgical judgment and his operative technique were excellent. He was always gentlemanly and courteous. He loved life and he loved people. A liberal in his thinking, he was easy in his judgments of his fellow men, affable, genial, personally attractive, ever ready with friendly encouragement or witty rejoinder. He died August 16, 1944, at the age of 76.

J. R. BUCHBINDER.

THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

THE publishing of *The Human Eye*[1] by Kronfeld, McHugh, and Polyak brings before us a beautiful example of a new form of color reproduction printed on transparent sheets. This is the first five color process rotogravure to be produced on an acetate base wherein every color is a process color involving tone etching. The binding of these transparent sheets is arranged so that two are held together with the two pictures in contact, back to back, on the inside, giving protection against marring—the pictures being viewed through the material. Turning the pages we observe both sides of a series of gross sections. Superimposing gives the effect of a three dimensional, translucent model.

The original paintings are the work of Gladys McHugh and are based on anatomical dissection and long study. Beside each picture is a brief panel description. These are completed by the second part of the volume, an explanatory text in the precise phrasing of Dr. Peter C. Kronfeld. Accuracy of detail in drawing and text is obvious to careful scrutiny.

A third section by Stephen L. Polyak, M.D., sums up "The History of Our Knowledge of the Structure and Functioning of the Eye."

Even if you are not interested in ophthalmology you will enjoy looking over this publication.

EARLE B. FOWLER

THE book *Oral Pathology*[2] was originally presented by Thoma in 1941. The reception of this excellent work warranted the preparation of the new second edition. The subject matter does not differ a great deal from the previous edition, but some new material has been added. The material is again classified in twelve parts. This division of the material provides for easy reference and each part follows the other in reasonable sequence. Emphasis is laid upon the value of experimental pathology and the graduate student will profit accordingly from experimental suggestions and guides.

The first 758 pages of the book are devoted essentially to the teeth and their supporting tissues, but the chapters on "The Modification of Growth and Development By Local Factors and Somatic Disease" and "Maldevelopment of the Face and Jaws and Mal-occlusion of the Teeth" are to be especially mentioned. Heredity and endocrine influences on the development of the teeth and jaws are the subjects of important chapters and the bibliographies are invaluable, as are those referring to the very inclusive chapter on "Nutritional Influences on Development." The section on dental caries, as in the first edition, is not satisfactory. Those familiar with caries investigation and accomplishment will not approve and the average reader and student will be confused. No phase of congenital malformations of the face and jaws has been neglected. Focal infection has been dealt with in a concise manner and the opinions expressed are acceptable and worthy of studious consideration. The remaining portion of the book is devoted to broader integration of diseases and affections of the maxillofacial tissues, with systemic disease.

Although many subjects are treated with brevity, the characteristic coverage of the subjects includes etiology, clinical findings, histologic picture and treatment. The book is profusely illustrated, but these vary in quality and utility. Many histologic reproductions are not well done. The book can be considered as an encyclopedia rather than a textbook and is a worthwhile addition to any dental or medical library.

FREDERICK W. MERRIFIELD

AFTER carefully studying and reviewing the 3d edition of Volumes 1 and 2 of Watson-Jones' work,[3] I am of the opinion that these books are the last word on our present treatment of fractures and joint injuries. Additional information has been gleaned from the author's experience in the present war. The illustrations, colored pictures, x-rays, and end-results are really a work of art.

This is one of the easiest fracture books to read that it has been my pleasure to review. It is comprehensive and gives the author's views of all the more common fractures and joint injuries encountered. True, there are some forms of treatments suggested that one may disagree with, but that is only natural when one covers the subject as Watson-Jones has in these volumes. Many sections are superior to the present day orthopedic and fracture references in that a clear explanation can be found along with recommendation for good bone and joint treatment. No one chapter should be selected as outstanding because all of them deserve creditable mention. His conservative views are to be admired and it is my personal opinion that these books are a real contribution to bone and joint surgery.

These volumes can be highly recommended for general practitioner and specialist.

JAMES J. CALLAHAN.

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AMERICAN COLLEGE OF SURGEONS

1944 CLINICAL CONGRESS CANCELLED TO AID WAR EFFORT

THE American College of Surgeons, upon action of its Board of Regents, has cancelled its annual Clinical Congress because of the acute war situation that has developed, involving greater demands than at any time in the past upon our transportation systems for the carrying of wounded military personnel, troops, and war material. The Congress was to have been held in Chicago, October 24 to 27.

Dr. Irvin Abell of Louisville, chairman of the Board of Regents, in making the announcement, said that this action was taken after consultation with the officials in Washington. Some of the replies which were received from these officials read in part as follows:

From Major General Norman T. Kirk, Surgeon General, United States Army:

"Naturally, we all like these meetings to be held and to attend them. However, from an official standpoint I must say we are needing more and more railroad transportation to move our battle casualties from the ports to our hospitals. And there are still many troops in the United States who require railroad transportation to ports in order to get them overseas. In addition, difficulty is being experienced in obtaining the necessary material to continue the battle. This means transportation for the raw materials that go into munitions and the shipping of these munitions to the ports after they are fabricated. Each month the need for this material overseas is increasing rather than diminishing.

"The war is far from won and I think we should all consider the war effort rather than the satisfaction of our individual desires. That should give us the answer. After seeing the bomb craters and destroyed homes, factories, and transportation facilities in Europe, I am not surprised that this nation feels it is far removed from war and that the war is about over. It isn't."

From R. C. Clare, Assistant Director, Passenger Section, Division of Traffic Movement, Office of Defense Transportation:

"This office cannot attempt to evaluate the importance or the essentiality of any particular meeting. We have attempted to clearly portray the present critical transportation situation. The transportation requirements of the armed forces are not at present being entirely satisfied. At the same time, soldiers and sailors on leave from duty overseas are unable to secure Pullman accommodations to their homes and frequently have to stand in coaches for considerable distances. The responsibility, therefore, rests upon the officers of your organization to determine if, in the light of these conditions, you should go through with your Chicago meeting.

"I believe you will agree that the Office of Defense Transportation cannot attempt to make this decision for you. We assure you that there is an urgent need for the curtailment of convention travel in order to clear the transportation channels of the country for the movement of military and essential civilian travel. We, therefore, ask for your serious consideration of our appeal in the light of this situation."

Feeling that the many factors in favor of holding the Clinical Congress, however important, are less vital than the assurance of adequate transportation and the best medical care for the wounded, as well as the clearance of transportation facilities so far as possible for the conveying of troops and war material, the American College of Surgeons willingly cancels, for the third successive year, its annual meeting, in order to aid the war effort. The Regents recognize that there is a great burden on the members of the surgical profession in their local communities as the result of the large proportion of the profession which is serving with the armed forces. They also take cognizance of the desire of the profession to do nothing which would interfere with the successful prosecution of the war program, such as would be caused by the temporary absence of its members from duties during the period of the Congress. More than three thousand surgeons and some two thousand hospital representatives usually attend the Clinical Congress.

At the annual meeting of the Board of Regents to be held later in the year, fellowship in the College will be conferred *in absentia* on the class of initiates of 1944. At the same time the list of hospitals, cancer clinics, medical services in industry, hospitals conducting programs of graduate training in surgery, and medical motion pictures, that meet the College standards, will be approved and later published. All present officers, regents, governors, and standing committees will continue in office.

War conditions permitting, the Clinical Congress will be held in the fall of 1945.